THE HAND
ITS ANATOMY AND DISEASES

THE HAND:

Its Anatomy and Diseases

By

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To Leslie and John

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Constant Sources of Enjoyment

and Inspiration

PREFACE AND ACKNOWLEDGMENTS

I am indebted to many people who knowingly or unknowingly have contributed to this book During the period before World War II Dr Henry Marble and Dr William Browne of Boston stimulated my interest in Hand Surgery by numerous lectures on this subject They were probably the only men in this area who devoted so much time to teaching this subject to scores of house officers and medical students

During World War II Dr Sterling Bunnell came to the Boston City Hospital and gave a brilliant lecture to the house staff which opened up a new view of the reconstructive possibilities in hand trauma He showed examples of hands seemingly hopelessly lost which regained useful function with the proper choice of operative procedure The inspirational value of this talk will never be forgotten

While in the Army I served as neurosurgeon under Dr Frank Mayfield and Dr Russell Meyers who taught me much concerning peripheral nerve injuries and their management

On joining the staff of the Boston City Hospital I was invited to serve on the Hand Service which had recently been organized by Dr J Edward Flynn This opportunity to see large numbers of hand cases in a short period of time and discuss them with other members of the Hand Service has been a rewarding experience for which I shall always be grateful to Dr Flynn Some of the photographs of interesting cases included in this book have been loaned me by members of the Hand Service

Many of the x rays of bone diseases have been selected from the files of the Boston City Hospital X ray Department by Dr Max Ritvo Director of the Department of Radiology Some of the fracture x rays were borrowed from the files of the Shortell Fracture Unit through the courtesy of Dr Albert M Moloney Roentgenologist in-Chief for Orthopedic Surgery Boston City Hospital

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I am grateful to the following editors for permission to reproduce illustrations from their respective journals Dr Thurston S Welton *The American Journal of Surgery* (Figures 38 42 44 45 46 52 58 59 66 67 75 77 88 109 110 135 140-147 153 154 163 166) Dr Austin Smith *The Journal of the American Medical Association* (Figures 86 87) and Dr Loyal Davis, *Surgery, Gynecology and Obstetrics* (Figure 39)

My deep appreciation goes to Mr William O Leary for the time consuming study and long hours of careful work that went into the clear concise drawings which he created for this book.

Special acknowledgment must be given my secretary Ruth E. Brody without whose unselfish and seemingly tireless devotion to duty this book never would have been completed. She has worked long and hard at editing typing and advising as well as being a constant source of encouragement

J J B

Part III
TRAUMA

THE HAND
ITS ANATOMY AND DISEASES

Part V

RECONSTRUCTIVE SURGERY

PART I

STRUCTURE AND DEVELOPMENT

CHAPTER I

ANATOMY

The anatomy of the hand will be presented by first describing the bony framework and then the more superficial structures. It is hoped that this sequence of exposition will give a three dimentional viewpoint and aid retention of the salient information.

BONES

The distal extremity of the *radius* is expanded into the carpal and ulnar articular surfaces. The carpal articular surface is triangular on the radial side for articulation with the navicular bone and quadrilateral on the ulnar side for articulation with the lunate bone. The ulnar articular surface is narrow and smooth and articulates with the head of the ulna and the base of the triangular cartilaginous articular disk. The dorsal surface of the distal radius is groved by the extensor tendons with the most prominent landmark being Lister's tubercle which separates the extensor pollicis longus from the extensor carpi radialis brevis (Fig. 1). The lateral surface of the distal end of the radius is prolonged as the styloid process which is grooved for the tendons of the abductor pollicis longus and extensor pollicis brevis.

The distal extremity of the *ulna* is slightly expanded to form a rounded articular surface which is prolonged medially as the styloid process. The articular surface or head of the ulna articulates with the triangular disk distally and with the ulnar articular surface of the radius laterally.

The proximal row of carpal bones consists of the navicular, lunate and triquetrum. The *pisiform* articulates with the triquetrum and really does not form a part of the proximal row. The *navicular* bone is on the radial side of the carpus with its long axis passing downward and laterally. It articulates proximally with the lower end of the radius; distally it has an articular surface for a juncture with the greater and lesser multangular. At the distal lateral angle of the ventral concave surface is the

The distal carpal row consists of the greater and lesser multangular capitate and hamate bones The *greater multangular* possesses a proximal surface which articulates with the navicular bone a distal saddle shaped articulation for the first metacarpal and a medial surface which articulates with the lesser multangular and second metacarpal There is a groove on the volar surface of

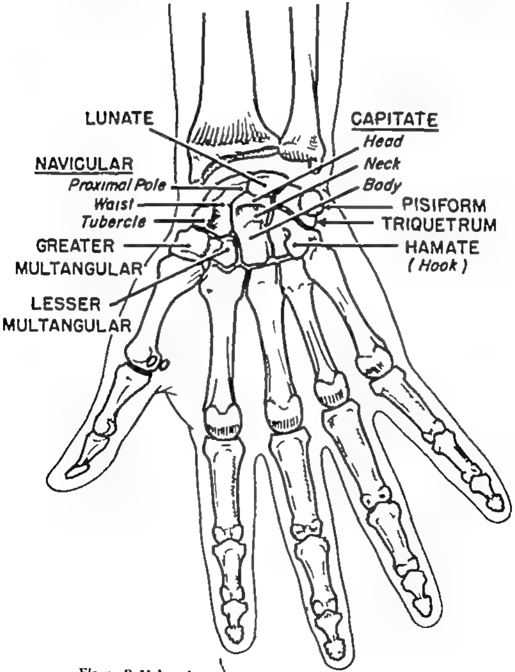

Figure 2. Volar view of the bones of the wrist and hand

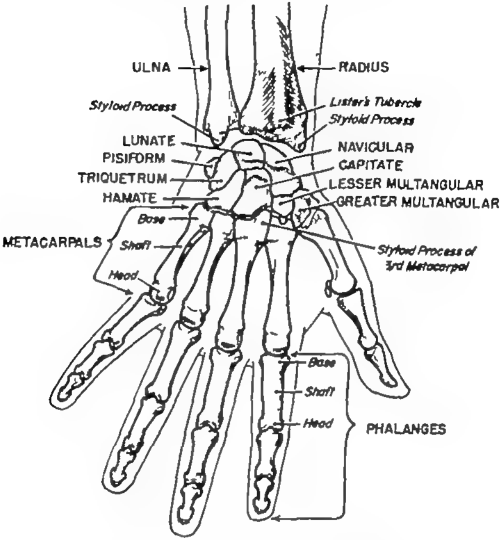

Figure 1 Dorsal view of the bones of the wrist and hand.

tubercle which may be grooved by the flexor carpi radialis (Fig 2) The medial surface has two articular faces for the capitate and lunate bones The *lunate* is characterized by its semilunar inferior articulation for the head of the capitate and hamate bones. The convex proximal surface articulates with the radius. There is a small lateral concave face for articulation with the navicular and a small medial quadrilateral face for juncture with the triquetrum The *triquetrum* presents a concave inferior surface for articulation with the hamate and a lateral quadrilateral articulating face for the lunate There is a small medial oval facet for articulation with the pisiform

heads of the proximal phalanges possess two small condyles and an intercondylar space

The *middle phalanges* are shorter than the proximal although of the same general appearance The bases present a double concavity to articulate with the condyles of the heads of the proximal phalanges The heads are very similar to the heads of the proximal phalanges The *distal phalanges* are similar for all the fingers possessing bases similar to those of the middle phalanges and short shafts which end in flat ungulate plates roughened on the volar surfaces

JOINTS

The wrist joint includes the following the distal radio-ulnar radio-carpal proximal intercarpal mid-carpal distal intercarpal and carpometacarpal (Fig 3) The *distal radio-ulnar* joint is a trochoid or pivot joint connected by a volar and dorsal radio-ulnar ligament and an articular triangular cartilaginous disk placed with its apex attached to the styloid process of the ulna and its

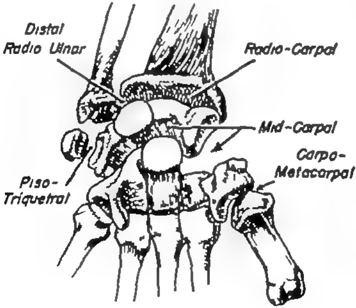

Figure 3 The more important spaces of the wrist joint.

base to the ulnar notch of the radius This possesses its own joint cavity lined with synovium and its movement consists of rotation of the radius against the head of the ulna The *radio-carpal* is a

the greater multangular produced by the flexor carpi radialis. The *lesser multangular* is a wedge shaped bone with four articular surfaces for the navicular proximally the greater multangular laterally the second metacarpal distally and the capitate medially The *capitate*, which is the largest of the carpal bones possesses a rounded articular head that articulates with the concavity formed by the navicular and lunate and a small neck and body The distal face articulates with the second, third and fourth metacarpal bones the lateral with the lesser multangular and the medial with the hamate The *hamate* is a wedge shaped bone with a volar prolongation or hook. The proximal surface articulates with the lunate the lateral with the capitate the inferior with the fourth and fifth metacarpals and the medial with the triquetrum

The metacarpal bones are divided into a proximal base, a longitudinal shaft with a volar concavity and dorsal convexity and a distal head. The base of the *first metacarpal* differs from the others in that it is concave-convex for articulation with the greater multangular to form a saddle joint. The *second metacarpal* has a peculiar notched appearance for articulation with the lesser multangular The radial shoulder of the notch articulates with the greater multangular and the ulnar shoulder with the capitate and styloid process of the base of the third metacarpal The base of the *third metacarpal* articulates with the capitate proximally the second metacarpal radially and the fourth metacarpal ulnarly This ulnar articulation is distinctive in that it consists of two small oval facets. On the dorsal radial angle there is a styloid process which extends upward over the capitate for insertion of the extensor carpi radialis brevis. The base of the *fourth metacarpal* articulates proximally with the hamate and capitate radially through two oval facets with the third metacarpal and ulnarly by a single concave articulation with the fifth metacarpal The *fifth metacarpal* articulates proximally with the hamate and radially with the fourth metacarpal. The heads of the metacarpals present convex articular surfaces for the proximal phalanges

The bases of the proximal *phalanges* present concave articulating surfaces. The shafts exhibit a volar concavity the ridges representing the insertions of the sheaths of the flexor tendons The

condyloid joint whereby the radius and articular disk articulate with the navicular lunate and triquetrum This joint is connected by volar and dorsal radio-carpal ligaments and ulnar and radial collateral ligaments. The ulnar collateral ligament extends from the styloid process of the ulna to the triquetrum transverse carpal ligament and pisiform The radial collateral ligament extends from the radial styloid process to the greater multangular and transverse carpal ligament. This joint possesses its own cavity lined by synovial membrane. The proximal carpal bones articulate with each other and are connected by dorsal volar and interosseous ligaments The pisiform bone maintains its integrity through a piso-hamate ligament connecting the pisiform to the hamate and a piso-metacarpal ligament connecting the pisiform to the base of the fifth metacarpal The articulation between the pisiform and triquetrum is lined with synovial membrane. The distal carpal bones are connected by dorsal, volar and interosseous ligaments. The interosseous ligament between the greater and lesser multangulars is sometimes lacking The *mid carpal joint* is the articulation of the proximal row with the distal row of carpal bones. It is a compound joint possessing in its center a ball-and-socket joint consisting of the head of the capitate and the concave surfaces of the navicular and lunate. On the radial side the multangulars articulate with the navicular and on the ulnar side the hamate articulates with the triquetrum forming arthrodial or gliding joints The mid-carpal joint is connected by volar and dorsal ligaments and a radial and ulnar collateral ligament on either side of the carpus An inconstant interosseous ligament may be present between the capitate and navicular This joint is lined with synovial membrane which sends prolongations between the various bones. If the interosseous ligament is absent between any of the bones of the distal row this joint may be continuous with the carpometacarpal joints The *carpometacarpal* articulations are held together by the dorsal volar and interosseous ligaments between the third and fourth metacarpals and the capitate and hamate These joints are arthrodial and permit very little movement The index and middle finger joints are almost immovable but the ring and fifth finger joints have motion This motion is of extreme importance when making a

fist or grasping objects and its lack is noticed often in injuries or disease associated with them The carpometacarpal articulation of the thumb is a saddle joint permitting a wide range of motion This possesses its own capsule and is lined by a synovial membrane

The movements of the wrist are fairly complex and have been well summarized by Kaplan[1] Volar flexion of the hand takes place mainly in the radio-carpal joint and secondarily in the mid carpal joint Dorsiflexion on the contrary occurs mostly in the mid-carpal joint and additionally in the radio-carpal joint Radial deviation occurs mostly in the mid-carpal joint and ulnar deviation mostly in the radio carpal articulation These changes are easy to reason since the dorsal lip of the radius would prevent the radio-carpal joint from contributing very much to extension and the radial styloid process would limit the radial deviation of this point However it must be realized that if one of these joints is fused the other will often compensate for its movement

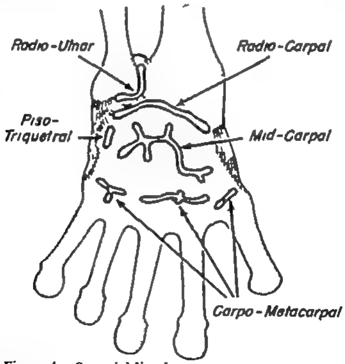

Figure 4 Synovial lined spaces of the wrist joint

Bradley and Sunderland[2] report a case where the mid-carpal joint was destroyed by bony fusion leaving as the sole functional joint the radio-carpal By studying this joint they concluded that the movements of flexion and extension occur in the radio-carpal

and mid-carpal joints and that the amount of movement occurring at the mid-carpal exceeds the radio-carpal Radial deviation was produced almost entirely in the mid-carpal joint and ulnar deviation was unaffected by the fusion of the mid-carpal joint.

There are usually seven synovial lined cavities in the wrist joint the distal radio-ulnar radio-carpal mid-carpal piso-triquetral metacarpo-carpal of the thumb second and third fourth and fifth fingers (Fig 4)

The carpometacarpal saddle joint of the thumb has a peculiar shape in that the articulating surface of the greater multangular possesses a convexity with a shorter radius on the ulnar than on the radial side (Fig 5a) As a consequence movement of this joint produces a rotation of the metacarpal as well as the usual flexion extension abduction adduction and circumduction It may be that this bony configuration is responsible for opposition rather than the muscle action of the opponens pollicis This observation has been made by many anatomists [3]

The second third and fourth metacarpal bones articulate with each other at their bases and are connected by dorsal volar and interosseous ligaments

The metacarpophalangeal joints are condyloid and possess a capsule which is reinforced laterally by the lateral collateral ligaments running in a volar direction from the proximal bone to the distal bone (Fig 5b) The volar aspect of the joint is reinforced by a strong ligament known as the palmar plate or glenoid ligament. These are loosely attached to the metacarpal bone but are firmly attached to the base of the first phalanges The dorsal surfaces of these joints are covered by expansions of the extensor tendons These joints permit flexion extension adduction, abduction and circumduction The metacarpophalangeal joint of the thumb differs greatly in individuals, and the motion of this joint varies depending upon whether the metacarpal has a flat or rounded head. With flat joints there is less mobility than in those with round heads.[4]

The phenomenon of cracking in the metacarpophalangeal joints of the fingers has long been a subject of discussion Roston and Haines [5] theorize that this is due to a sudden wide separation of the bones of this joint when the joint capsules are lax per

mitting a partial vacuum to become occupied by water vapor and blood gases under reduced pressure

The interphalangeal joints are quite similar to the metacarpophalangeal joints as far as the joint cavities and collateral and volar ligaments are concerned However they differ in shape since they are hinge joints and permit only flexion and extension (Fig 5c)

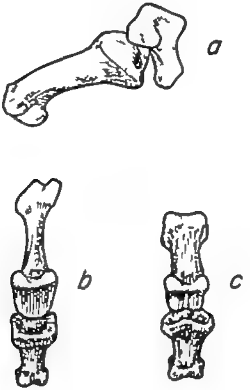

Figure 5 Diagram of the shape of (a) the carpometacarpal joint of the thumb (b) metacarpophalangeal joint and (c) interphalangeal joint

SESAMOID BONES

The sesamoid bones, which derive their name from *Sesamum indicum* an ancient East Indian plant used by Greek physicians for purging, are said to have been given their name by Galen Hubay[8] studied 299 male and 230 female hands and found that in 100 per cent of the cases the radial and ulnar sesamoid bones of the metacarpophalangeal joint of the thumb were present in 70 per cent the ulnar sesamoid bone of the fifth metacarpophalangeal joint was present in 40 5 per cent the radial sesamoid bone of the second metacarpophalangeal joint was found and

in only 0 8 per cent a radial sesamoid of the metacarpophalangeal joint of the third and fourth fingers was present.

Joseph [7] found a similar frequency of sesamoids and re-emphasized the fact that these bones do not develop as a response to local and environmental factors such as rubbing or pressure They regularly appear between the ages of thirteen and eighteen in the male and eleven and fifteen in the female indicating that ossification of these bones is determined by factors similar to those which determine the ossification of any other bone in the body These sesamoids are embedded in the capsule of the joint and have articular surfaces which articulate with the underlying bones

MUSCLES

The *muscles that move the hand consist of the intrinsic muscles* whose origins and insertions are limited to the hand region and the extrinsic muscles which come from the forearm and pass over or under the wrist to move the fingers or wrist

The intrinsic muscles consist of the thenar muscle group the hypothenar muscle group and the interossei and lumbricales The hypothenar muscle group is composed of four muscles the palmaris brevis abductor digiti quinti flexor digiti quinti brevis and opponens digiti quinti The *palmaris brevis* is a thin flat muscle placed beneath the skin on the ulnar side of the hand which arises from the transverse carpal ligament and palmar aponeurosis and inserts into the skin on the ulnar surface of the hand Direct pressure over the pisiform bone produces a corrugation of the skin on the ulnar border of the hand the so-called palmaris brevis reflex The *abductor digiti quinti* forms the convex outline of the hypothenar eminence It extends from the pisiform bone and the tendon of the flexor carpi ulnaris with which it forms a functional unit for abduction of the fifth finger and inserts into the ulnar side of the base of the proximal phalanx and extensor hood of the fifth metacarpophalangeal joint (Fig 6) The *flexor digiti quinti brevis* lies radial to the preceding muscle arises from the hook of the hamate bone and the transverse carpal ligament and inserts into the ulnar side of the base of the first phalanx of the little finger The deep branch of the ulnar nerve descends into the deep aspect of the palm through the origins

the greater multangular and inserts into the radial side of the base of the first phalanx of the thumb The *flexor pollicis brevis* is a complex muscle which various anatomists have divided into several portions The superficial portion arises from the transverse carpal ligament and ridge of the greater multangular just ulnar to the abductor pollicis brevis and inserts into the radial side of the base of the first phalanx by way of the radial sesamoid bone The deep portion arises from the ulnar surface of the first metacarpal bone and inserts into the ulnar side of the base of the first phalanx through the ulnar sesamoid bone of the joint This deep portion is essentially a part of the adductor pollicis The *opponens pollicis* lies beneath the preceding abductor and flexor pollicis brevis arises from the ridge of the greater multangular and transverse carpal ligament and inserts into the whole length of metacarpal bone

The *adductor pollicis* consists of an oblique and a transverse portion The transverse portion is triangular in form and arises from the volar surface of the third metacarpal bone Its fibers converge to insert into the ulnar side of the base of the first phalanx of the thumb in continuity with the ulnar sesamoid bone of this joint. The oblique portion arises from the bases of the second and third metacarpals and capitate bone and inserts into the ulnar side of the base of the first phalanx of the thumb by way of the ulnar sesamoid bone.

The abductor pollicis brevis the opponens pollicis, and the superficial head of the flexor pollicis brevis are usually supplied by the median nerve and the short head of the flexor brevis and adductor pollicis by the ulnar nerve

The interossei supplied by the ulnar nerve consist of four dorsal and three volar muscles The *dorsal interossei* are bipenniform muscles which arise from the adjacent sides of the metacarpal bones and converge as lateral bands of the extensor apparatus of the fingers (Fig 7) The first dorsal interosseous arises by two heads through which the radial artery passes into the palm of the hand. It inserts into the radial side of the index finger and produces the abduction of this finger so important for the pinch mechanism between the index finger and thumb The second and third dorsal interossei insert into the radial and ulnar sides

of the extensor apparatus of the middle finger The fourth interosseous inserts into the ulnar side of the extensor apparatus of the ring finger Thus the dorsal interossei abduct the index and ring fingers away from the midline and move the middle finger in a lateral and medial direction

Fyler and Markee[8] studied the insertions of the dorsal interossei and found that their tendons pass directly over the axis of rotation of the metacarpophalangeal joint to insert into the base of the proximal phalanx or lateral band of the extensor apparatus The first dorsal interosseous inserts into bone in 100 per cent of cases, second 60 per cent third 6 per cent and fourth 40 per cent. The remainder of each muscle inserts into the lateral band

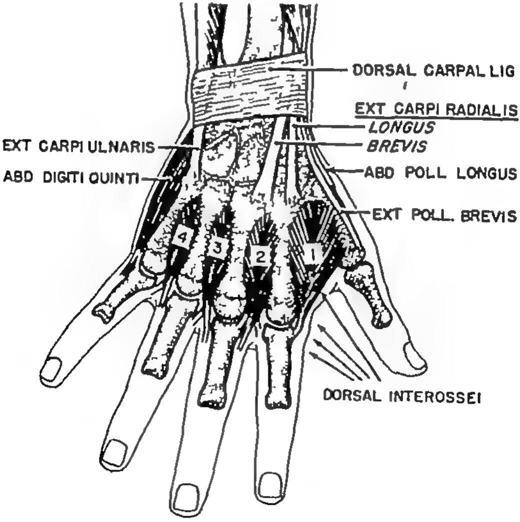

Figure 7 Dorsal view of hand showing the dorsal interossei muscles.

The three *volar interossei* have as one of their main functions adduction of the fingers toward the middle finger Consequently the first interosseous arises from the ulnar side of the second metacarpal bone and inserts into the same side of the extensor mechanism of the index finger· the second arises from the radial side of the fourth metacarpal bone and inserts into the radial side of the base of the extensor apparatus of the ring finger the third arises in a similar manner from the radial side of the fifth metacarpal and inserts into the same side of the little finger (Fig 6) Eyler and Markee [8] found that the tendons of the volar interossei

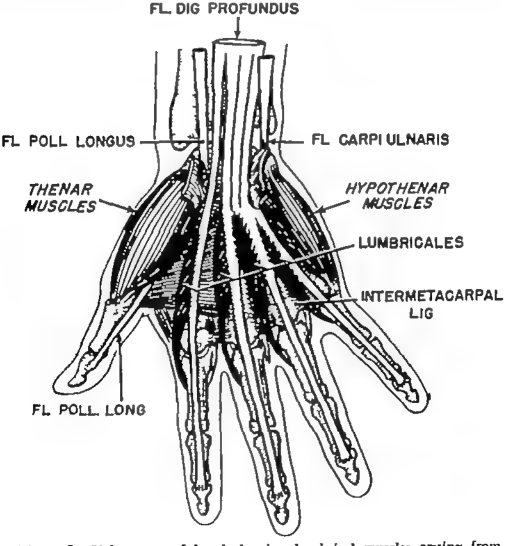

Figure 8 Volar view of hand showing lumbrical muscles arising from the flexor profundus digitorum.

pass below the axis of rotation of the metacarpophalangeal joint and insert primarily into the lateral bands with only minor insertions onto the bases of the proximal phalanges

There are usually four lumbrical muscles arising from the radial side of the tendons of the flexor digitorum profundus (Fig 8) The third and fourth lumbricals may arise from contiguous tendons Each lumbrical muscle passes along the radial side of the corresponding finger volar to the intermetacarpal ligament and inserts into the extensor apparatus The attachment of the lumbricals to the flexor digitorum profundus is a firm one Not only does the lumbrical flex the metacarpophalangeal joint and help extend the two distal joints of the finger but it also draws the flexor tendon distally The classical arrangement of the four lumbricals passing to the radial side of the finger is present in only 39 per cent of the cases in a recent study by Sunderland [9] The first and second lumbricals rarely vary The third lumbrical may have a double insertion onto the radial side of the ring finger and the ulnar side of the middle finger or an insertion into the ulnar side of the middle finger The fourth lumbrical may split and insert into the ulnar side of the ring and radial side of the little finger or it may insert solely into the ring finger Sunderland [10] believes that the lumbrical muscles produce some degree of rotation in the radial direction of the metacarpophalangeal joint of the fingers to which they insert The first and second lumbricals are supplied by the median nerve and the third and fourth by the ulnar nerve

The extrinsic flexor muscles of the hand are divided into superficial and deep groups The superficial group consists of the pronator teres flexor carpi radialis palmaris longus flexor carpi ulnaris and flexor digitorum sublimus These muscles originate at the medial epicondyle of the humerus The *pronator teres* (median nerve) rises from two heads the humeral from the common origin of the other muscles of the superficial group and the ulnar head from the coronoid process of the ulna The median nerve enters the forearm between the two heads of this muscle After crossing the forearm this muscle inserts into the middle of the lateral surface of the body of the radius The *flexor carpi radialis* (median nerve) pases down the forearm and inserts into

the base of the second metacarpal bone after passing over the tuberosity of the navicular and grooving the greater multangular bone

The *palmaris longus* (median n) arises with the other superficial flexors of the forearm and inserts into the transverse carpal ligament and palmar aponeurosis This muscle is apt to be missing George[11] found it to be present bilaterally in 78.3 per cent of 276 cadavers. It was present in the right side only in 6 1 per cent the left side only 6 9 per cent, absent on both sides 8 7 per cent In other words the palmaris longus was absent in 15 [illegible] per cent of 552 limbs Occasionally this muscle sends a small tendon to the short muscles of the thumb

The *flexor carpi ulnaris* (ulnar n.) arises by two heads one from the medial condyle of the humerus and the other from the medial aspect of the olecranon and ulna The ulnar nerve passes into the forearm through these two heads This muscle continues down the ulnar border of the forearm and its tendon inserts through the pisiform bone into the hamate and fifth metacarpal by way of the piso-hamate and piso-metacarpal ligaments.

The *flexor digitorum sublimis* (median n) arises from the medial epicondyle of the humerus the medial aspect of the coronoid process and the oblique line of the radius separating it into two portions a superficial and deep The superficial portion gives rise to two tendons for the middle and ring fingers and the deep portion gives off two tendons for the index and little fingers The four tendons keep this arrangement as they pass under the transverse carpal ligament from whence they diverge to insert into the fingers. At approximately the base of the first phalanx each tendon splits to allow passage of the profundus tendon reuniting dorsally to insert into the middle phalanx As the fibers reunite they form the chiasm of Camper (Fig 9)

The deep group of forearm flexors consist of the pronator quadratus, the flexor digitorum profundus and the flexor pollicis longus. The *flexor digitorum profundus* arises from the upper two-thirds of the ulna and interosseous membrane. It passes down the forearm as a tendon sheet which separates into four tendons Each profundus tendon passes through the perforation in the sublimis tendon to its insertion into the distal phalanx

(Fig 9) The flexor digitorum profundus tendon to the index finger usually splits from the common tendon mass at a higher level than the rest of the tendons and as a consequence has more freedom of motion (Fig 8) Since the third fourth and fifth fingers usually arise from the common tendon mass more distally than the index finger there is less individual profundus motion in these fingers. The tendons to the index and middle fingers are supplied by the median nerve and the tendons to the ring and little fingers by the ulnar nerve

Wilkinson [15] studied the insertions of these tendons into the

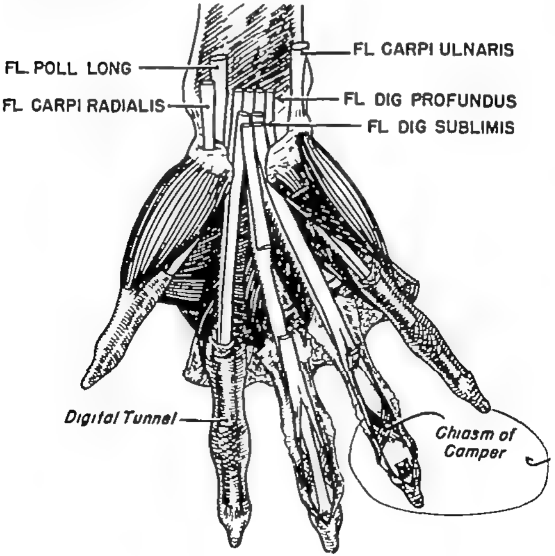

Figure 9 Volar view of hand showing insertions of the flexor sublimis and profundus tendons.

finger and found that the tendon fibers consist of two portions superficial and deep The superficial tendon fibers pass to lateral insertions in the terminal phalanx and the deep tendon fibers pass to more central and distal insertions

The *flexor pollicis longus* (median n) arises from the upper two-thirds of the body of the radius and adjacent interosseous membrane Its tendon passes beneath the transverse carpal liga ment and diverges radially along the digital tunnel of the thumb to insert into the base of the distal phalanx (Fig 8) In this regard, Wilkinson[12] finds that the thumb has a slightly different arrangement of fibers than the other fingers The super ficial tendon fibers pass to the central and more distal insertions whereas the deep tendon fibers possess lateral insertions This is completely opposite to the arrangement of the profundus tendon fibers in the fingers He also finds a vestigial tendon present in about 28 per cent of the flexor pollicis tendon sheaths examined These are discrete glistening, intra vaginal tendons which fuse with the synovial membrane on either side of the long tendon opposite the metacarpophalangeal joint and usually insert as a single slender tendon into the ulnar part of the volar aspect of the palmar ligament of the interphalangeal joint This is the so-called polliceal perforatus tendon

The extensor muscles of the forearm similarly may be divided into a superficial and deep group The superficial (radial n) consists of the brachioradialis extensor carpi radialis longus and brevis extensor digitorum communis extensor digiti quinti proprius and extensor carpi ulnaris The *brachioradialis* arises from the upper two-thirds of the lateral supracondylar ridge of the humerus and the lateral intermuscular septum and continues distally in the forearm as a flat tendon which inserts into the radial styloid process The *extensor carpi radialis longus* originates from the lower third of the lateral supracondylar ridge of the humerus and intermuscular septum and continues down the fore arm to become a flat tendon which inserts into the base of the second metacarpal The *extensor carpi radialis brevis* arises from the lateral epicondyle of the humerus and the radial collateral ligament of the elbow and passes down the forearm to insert into the styloid process of the third metacarpal bone The *extensor*

digitorum communis arises from the lateral epicondyle of the humerus and intermuscular septum and passes down the forearm to split into four tendons which insert into the bases of the middle phalanges (Fig 10) The *extensor digiti quinti proprius* arises in conjunction with the common extensor tendon passes down the forearm to insert alongside the common extensor tendon of the fifth finger The extensor digiti quinti proprius usually divides in two as it crosses the back of the hand The *extensor carpi ulnaris* arises from the lateral epicondyle of the humerus from the dorsal border of the ulna and deep fascia of the forearm and passes down the forearm to insert into the base of the fifth metacarpal bone

As the extensor tendons to the fingers reach the metacarpophalangeal joints they usually are attached by interlacing tendinous slips called vincula (Fig 10) Leslie[13] studied the arrange

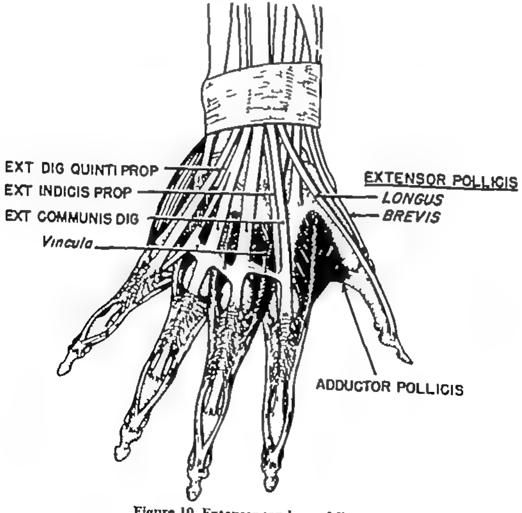

Figure 10 Extensor tendons of fingers.

finger and found that the tendon fibers consist of two portions superficial and deep The superficial tendon fibers pass to lateral insertions in the terminal phalanx and the deep tendon fibers pass to more central and distal insertions

The *flexor pollicis longus* (median n) arises from the upper two-thirds of the body of the radius and adjacent interosseous membrane Its tendon passes beneath the transverse carpal ligament and diverges radially along the digital tunnel of the thumb to insert into the base of the distal phalanx (Fig 8) In this regard Wilkinson [13] finds that the thumb has a slightly different arrangement of fibers than the other fingers The superficial tendon fibers pass to the central and more distal insertions whereas the deep tendon fibers possess lateral insertions This is completely opposite to the arrangement of the profundus tendon fibers in the fingers He also finds a vestigial tendon present in about 28 per cent of the flexor pollicis tendon sheaths examined These are discrete glistening intra vaginal tendons which fuse with the synovial membrane on either side of the long tendon opposite the metacarpophalangeal joint and usually insert as a single slender tendon into the ulnar part of the volar aspect of the palmar ligament of the interphalangeal joint. This is the so-called "polliceal perforatus" tendon

The extensor muscles of the forearm similarly may be divided into a superficial and deep group The superficial (radial n) consists of the brachioradialis extensor carpi radialis longus and brevis extensor digitorum communis extensor digiti quinti proprius and extensor carpi ulnaris The *brachioradialis* arises from the upper two-thirds of the lateral supracondylar ridge of the humerus and the lateral intermuscular septum and continues distally in the forearm as a flat tendon which inserts into the radial styloid process The *extensor carpi radialis longus* originates from the lower third of the lateral supracondylar ridge of the humerus and intermuscular septum and continues down the forearm to become a flat tendon which inserts into the base of the second metacarpal The *extensor carpi radialis brevis* arises from the lateral epicondyle of the humerus and the radial collateral ligament of the elbow and passes down the forearm to insert into the styloid process of the third metacarpal bone The *extensor*

separated from the extensor carpi radialis brevis by Lister's tubercle around which it passes to proceed to the terminal phalanx of the thumb. The *extensor indicis proprius* arises from the ulna and interosseous membrane distal to the extensor pollicis longus and passes under the dorsal carpal ligament in the same compartment with the extensor digitorum communis to join the ulnar side of the tendon of the extensor digitorum communis to the index finger.

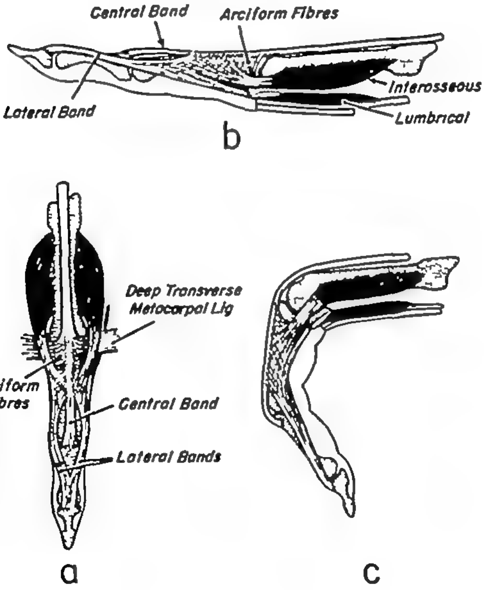

Figure 11. Extensor apparatus of fingers. (a) dorsal view (b) lateral view in extension (c) lateral view in flexion.

ment of the vincula and found a common recurring pattern The communicating slips pass obliquely and radially and those arising from the ulnar tendons are stronger and thicker than those from the radial ones The slip joining the ring finger with the fifth pulls the tendon of the fifth from its usual course so that it lies close to the tendon of the ring finger Consequently one of the tendons of the extensor digiti quinti proprius may be confused with the extensor communis to the fifth finger This bifid arrangement of the extensor digiti quinti was found in 112 of 127 cases with numerous variations in the remainder such as single or triple

The deep extensor muscles (deep radial n) consist of the abductor pollicis longus extensor pollicis longus and brevis, and the extensor indicis proprius The *abductor pollicis longus* arises just below the supinator muscle from the ulnar interosseous membrane and radius It passes obliquely downward and ends in a tendon which crosses over the extensor carpi radialis longus and brevis to insert into the radial aspect of the base of the first metacarpal There is great variation in this tendon s insertion For example Coleman *et al* [11] found in a study of 175 specimens that the most common insertions were as follows into base of first metacarpal and greater multangular 56 per cent, into first metacarpal alone 16 7 per cent into first metacarpal with additional attachment to abductor pollicis brevis 14 9 per cent The remaining variations were numerous and included accessory tendon slips to the opponens pollicis and the volar carpal ligament. This high percentage of aberrant tendinous insertions (83 per cent) is in agreement with most other studies [13] The *extensor pollicis brevis* arises just below the previous muscles from the radius and interosseous membrane passes distally through the abductor groove on the lateral lower third of the radius and inserts into the base of the first phalanx of the thumb Rarely this tendon may give off a tendinous slip to the base of the first metacarpal bone [14] Occasionally it passes over the radial head in an osteo-fibrous groove separate from the abductor pollicis longus The *extensor pollicis longus* arises just distal to the abductor pollicis longus from the ulna and interosseous membrane and courses down the forearm to the end of the radius where it is

Flexion of the distal interphalangeal joints places tension on the lateral bands which is transmitted through these oblique fibers to the proximal phalanx thereby flexing the proximal inter phalangeal joint Simultaneously flexion of the proximal inter phalangeal joint pulls the dorsal hood distally thus preventing the lateral bands from extending the distal joint This latter mechanism explains the well known fact that flexion of the proximal interphalangeal joint prevents active extension of the distal joint

There has been much debate regarding the exact function of the extensor apparatus As a rule the interossei and lumbricals flex the metacarpophalangeal joint and extend the two distal joints The extensor tendon extends the distal and middle inter phalangeal joints only when the metacarpophalangeal joint is flexed Extension of the metacarpophalangeal joint shifts the dorsal aponeurosis proximally slackens the arciform fibers and permits the intrinsic muscles to extend the interphalangeal joints (Fig 11b) Simultaneously the lumbrical muscle pulls the profundus tendon distally thereby nullifying its opposing effect Flexion of the metacarpophalangeal joint shifts the dorsal hood distally relaxes the central tendon s attachment to the proximal phalanx and permits its full play on the middle phalanx and on the lateral bands by way of the arciform fibers (Fig 11c) In addition this position places the interossei and lumbricals at poor mechanical advantage so that they cannot function properly Backhouse and Catton [21] made an interesting electromyographic study of lumbrical muscle function and found that its principle action is extension of the interphalangeal joints When the inter phalangeal joints are held in extension it is a weak metacarpophalangeal flexor which appears to have no effect on radial deviation or rotation of a finger

FASCIA

The superficial fascia of the hand consists of two layers an outer fatty layer and an inner layer of fairly uniform thickness These layers are continuous on the dorsal and ventral surfaces and form a glove like covering for the hand The outer layer varies in thickness forming fat pads over the thenar and hypo-

The insertions of the interossei lumbricals and extensor tendons into the fingers form a complex structure known as the extensor or dorsal apparatus of the finger which has been studied by many anatomists[9, 10-21] Generally the extensor communis tendon at the distal end of the proximal phalanx splits into three components a central band and two lateral bands (Fig 11a) The central band inserts into the proximal portion of the middle phalanx and reinforces the dorsal capsule of the proximal interphalangeal joint The lateral bands pass over the lateral surface of the proximal interphalangeal joint and converge over the middle phalanx to form another central tendon which inserts into the proximal portion of the distal phalanx after reinforcing the dorsal aspect of the distal interphalangeal joint The interossei and lumbrical tendons pass on either side of the metacarpophalangeal joints to unite with the lateral bands of the extensor communis tendon and continue with these to insert into the distal phalanx

A thin layer of fascia extends in an arciform manner from the extensor communis tendon to the interosseous and lumbrical tendons in the region of the metacarpophalangeal joints giving this structure the appearance of a hood There is a gliding attachment of the central tendon to the dorsal capsule of the metacarpophalangeal joint and to the proximal phalanx which on hyperextension of the metacarpophalangeal joint prevents the central tendon from extending the proximal interphalangeal joint.

The extensor apparatus of the fingers is bound in two locations to the retinacular tissue on the ventral surface of the finger in order to prevent lateral displacement. Over the metacarpophalangeal joint there is thin fascia which attaches the extensor hood to the strands of the palmar fascia and to the transverse metacarpal ligament. Over the proximal interphalangeal joints a thin layer of fascia proceeds to the underlying flexor digital tunnel Landsmeer[17] studied this lateral attachment over the proximal interphalangeal joint and found that in addition to a transverse layer extending from the extensor apparatus into the flexor tendon sheath there is an oblique group of fibers passing from the lateral bands into the lateral border of the proximal phalanx A similar set of fibers has been studied by Haines[20]

The palmar aponeurosis possesses transverse fibers which lace the pretendinous bands together and end over the metacarpophalangeal joints to form the superficial transverse ligament The aponeurosis is firmly attached to the bony framework of the hand by anchoring fibers which arise from the undersurface of the palmar aponeurosis and pass on either side of the flexor tendons of each finger forming eight separate groups of fibers which fuse with the interosseous fascia (Fig 13) The septa to the index finger and to the lateral side of the middle finger are shorter than the other groups since they unite with the interosseous

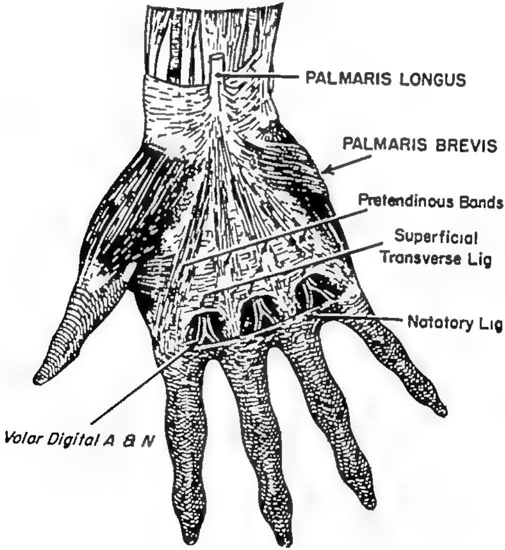

Figure 12. Palmar fascia.

thenar eminences and volar surfaces of the web spaces. It is practically non-existent in the central portion of the palm The inner layer which contains the cutaneous nerves and vessels, is separated from the deep fascia by an areolar cleavage plane most marked on the dorsum of the hand and absent in the central palm.

The deep fascia similarly consists of two layers which invest the bones and interosseous muscles and form compartments traversed by the extrinsic hand tendons The outer layer is usually the external walls of such compartments and the inner layer invests the bones and adjacent intrinsic musculature In areas devoid of moving extrinsic tendons (thenar and hypothenar areas or first dorsal interosseous muscle) these layers fuse to form a single lamina The deep fascia may be dissected free of the underlying interosseous fascia which is actually a perimysium When the deep layer passes over exposed periosteum it usually becomes fused to it thereby preventing sliding parts from becoming laterally displaced during movement of the hand and fingers.

The outer layer of the deep fascia of the flexor surface of the hand is modified to form the transverse and volar carpal ligaments and the palmar fascia whereas the inner layer forms the interosseous and metacarpal fascia, the transverse intermetacarpal ligament and the digital flexor tunnels.

The *volar carpal ligament* invests the flexor tendons in the distal part of the forearm as they enter the wrist (Fig 6) The *transverse carpal ligament* is a strong fibrous band which extends from the pisiform and hook of the hamate bone to the tuberosity of the navicular and the ridge of the greater multangular bones. The edge of this structure is quite distinct proximally Distally it merges into the palmar fascia (Fig 6)

The *palmar fascia* or aponeurosis is a triangular layer of fascia its apex continuous with the transverse carpal ligament where it may unite with the palmaris longus (Fig 12) The palmar fascia blends medially and laterally with the fascia over the thenar and hypothenar eminences and fans out over the heads of the metacarpals. The portion of fascia over each underlying tendon is thickened and is called the pretendinous band.

Each pretendinous band gives off superficial fibers to the skin of the palm and blends with the superficial fascia of the fingers

The palmar aponeurosis possesses transverse fibers which lace the pretendinous bands together and end over the metacarpo phalangeal joints to form the superficial transverse ligament The aponeurosis is firmly attached to the bony framework of the hand by anchoring fibers which arise from the undersurface of the palmar aponeurosis and pass on either side of the flexor tendons of each finger forming eight separate groups of fibers which fuse with the interosseous fascia (Fig 13) The septa to the index finger and to the lateral side of the middle finger are shorter than the other groups since they unite with the interosseous

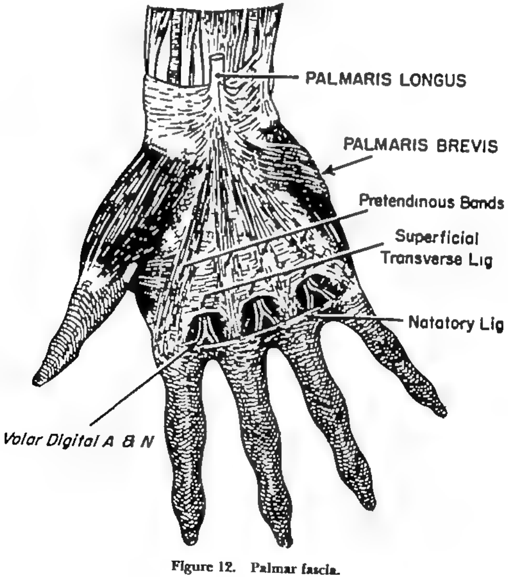

Figure 12. Palmar fascia.

fascia beyond the distal border of the adductor pollicis transversus The most medial septa is the longest and attaches to the fifth metacarpal bone as far proximally as the hook of the hamate and separates the fourth volar interosseous muscle from the opponens digiti minimi This has been called the internal intermuscular septum Proximally the septa present sharp crescentic borders and distally they end along side the fibrous digital sheath and blend with the transverse metacarpal ligaments and the periosteum of the proximal phalanges. Thus the tendons of the middle ring and little fingers are held firmly in place as they traverse the palm until they reach their appropriate fibrous digital sheath Jamieson [22] believes that this increase in connective tissue septa along the fourth and fifth fingers explains the greater incidence of Dupuytren s contracture in these fingers

There is another layer of transverse fibers distal to the palmar aponeurosis which spans the web spaces of the fingers known as the natatory ligaments (Fig 12)

The *deep transverse metacarpal* ligament is a continuous band of fascia which extends from the fifth finger to the index finger across the heads of the second third fourth and fifth metacarpals (Fig 6) It blends with the volar or palmar plates of the metacarpophalangeal articulations where its surface is grooved by the flexor tendons that pass over it

The *fibrous tendon or digital sheaths* of the flexor tendons of the fingers and thumb consist of fibrous tunnels from the head of the metacarpal bones to the distal phalanges (Fig 9) These canals are adherent to the head of the metacarpal the proximal and middle phalanx, and the proximal portion of the distal phalanx of the fingers and thumb The sheaths are very strong over the middle and proximal phalanges of the fingers and the proximal phalanx of the thumb but are much thinner opposite the joints

The deep fascia of the dorsum of the hand has been studied by Anson *et al* [23] who found that the outer layer is continuous with the antibrachial fascia and is modified over the wrist to form the *dorsal carpal ligament* On either side of the hand it becomes fused with the second and fifth metacarpals in conjunction with the inner layer forming a compartment through which the extensor tendons can move freely Distally it fuses with the capsules

of the metacarpophalangeal joints and adjacent periosteum The inner layer invests the underlying carpal and metacarpal bones and interosseous muscles It fuses laterally and medially with the outer layer along the second and fifth metacarpals and these layers continue as one over the first dorsal interosseous and abductor digiti quinti

TENDON SHEATHS

The tendon sheaths of the index middle and ring fingers extend from the insertion of the flexor profundus tendon in the distal phalanx to approximately the mid palmar crease (Fig 13)

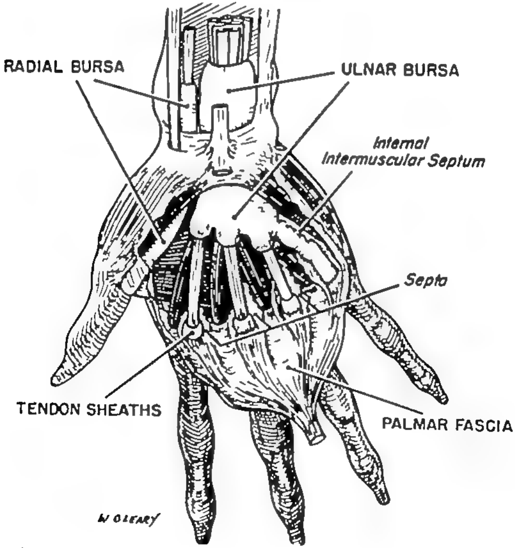

Figure 13 Palmar fascia dissected off palm showing the septa to the interosseous fascia and the most frequent arrangement of tendon sheaths

The tendon sheath of the fifth finger extends from the insertion of the profundus tendon in the distal phalanx to the wrist under the carpal tunnel The portion of this tendon sheath in the palm is called the ulnar bursa This enlarges to invest the flexor tendons to the fingers and is arranged in three communicating compartments the superficial anterior[1] to the tendons of the flexor sublimis the middle between the tendons of the sublimis and profundus the posterior dorsal to the tendons of the flexor profundus The lumbrical muscles are outside of the ulnar bursa The tendon sheath of the thumb begins at the insertion of the

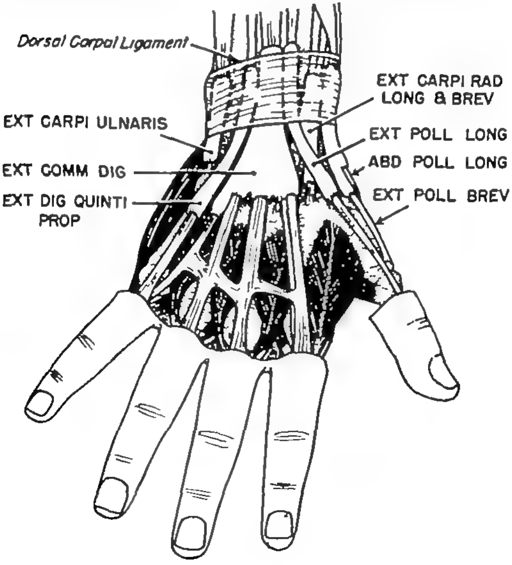

Figure 14 Usual pattern of dorsal tendon sheaths.

flexor pollicis longus tendon in the distal phalanx and extends into the wrist through the carpal canal The extension of this tendon sheath into the palm is called the radial bursa This arrangement of tendon sheaths of the flexor tendons is present in approximately 70 per cent of investigated cases[21] In 17 per cent of the series the tendon sheath of the fifth finger does not communicate with the ulnar bursa In a small percentage of cases the tendon sheaths of the index middle or ring fingers communicate with the ulnar bursa and occasionally all these tendon sheaths are connected with the ulnar bursa This variation in tendon sheath anatomy may well explain the occasional clinical cases in which infection from a tendon sheath of one finger spreads to a tendon sheath of an adjacent finger[22]

There are usually six dorsal tendon sheaths which contain the following extensor tendons as they pass under the dorsal carpal ligament the abductor pollicis longus and extensor pollicis brevis the extensor carpi radialis longus and brevis the extensor pollicis longus the extensor digitorum communis and extensor indicis proprius the extensor digiti quinti proprius the extensor carpi ulnaris (Fig 14) Rarely when the extensor pollicis brevis and abductor pollicis longus cross the radial styloid in separate grooves each has a separate tendon sheath

NERVES

The *median nerve* enters the forearm between the heads of the pronator teres and passes beneath the flexor digitorum sublimis to the lower third of the forearm where it becomes superficial lying under the radial aspect of the palmaris longus The muscles supplied by the median nerve in the forearm are the pronator teres the flexor carpi radialis the palmaris longus the flexor digitorum sublimis the flexor pollicis longus and the second and third flexor pollicis profundus tendons This nerve passes underneath the transverse carpal ligament to enter the palm of the hand where it splits into two portions a medial and lateral division (Fig 15) The lateral portion supplies a small branch to the muscles of the thumb i e the abductor brevis the opponens the superficial head of the flexor brevis and the first and second lumbricals It then divides into the three proper digital nerves

two of which supply the thumb and the third the radial side of the index finger The medial portion of the nerve divides into two common volar nerves which pass to the second and third web spaces where they divide into the proper digital nerves for the adjacent sides of the appropriate fingers

The median nerve supplies sensation to the palmar aspect of the hand on a line bisecting the ring finger On the dorsal surface of the hand it supplies the dorsal surface of the distal phalanx of the thumb index, middle and radial half of the ring finger A palmar branch leaves the median nerve in the lower third of the forearm to pierce the volar carpal ligament and supply the skin over the ball of the thumb and proximal portion of the palm

The *ulnar nerve* enters the elbow from behind the medial epicondyle of the humerus passes between the two heads of the flexor carpi ulnaris and descends under the cover of this muscle to the wrist. In the forearm it supplies the flexor carpi ulnaris and the flexor digitorum profundus to the fourth and fifth fingers and gives off a dorsal branch which supplies the dorsum of the hand medial to a line bisecting the ring finger The main body of the nerve crosses the transverse carpal ligament just radial to the pisiform bone and divides into a superficial and deep branch The superficial branch becomes the proper volar digital branch of the ulnar side of the fifth finger and the common volar digital branch which supplies the adjacent areas of the fourth and fifth fingers The deep branch passes between the abductor digiti quinti and flexor digiti quinti brevis perforating the opponens digiti quinti muscle at its insertion to pass to the dorsal surface of the palm supplying the muscles of the hypothenar eminence the seven interossei the lumbricals to the fourth and fifth fingers and the adductor pollicis (Fig 15b)

Anomalous motor innervation of the various muscles in the hand by the ulnar and median nerve may take place Rowntree[29] found that the innervation of the intrinsic muscles as usually described is present in only 15 5 per cent of 226 cases In 32 per cent, the flexor brevis pollicis was solely supplied by the ulnar nerve In 33 per cent, both heads were supplied completely by the median nerve Other outstanding anomalies were as follows all the thenar muscles supplied by the ulnar nerve in 2 per

cent the thenar and adductor pollicis muscles supplied by the median nerve in 2 per cent the thenar muscles including the adductor pollicis and first dorsal interosseous supplied by the median nerve in 1 per cent

Murphey *et al*[17] similarly found anomalous innervation In four cases of 698 ulnar nerve injuries the first dorsal interosseous was found to be innervated by the median nerve In two cases the flexor pollicis brevis had an anomalous innervation In one case the abductor minimi digiti was supplied by the median nerve and in another the opponens pollicis was supplied by the ulnar nerve

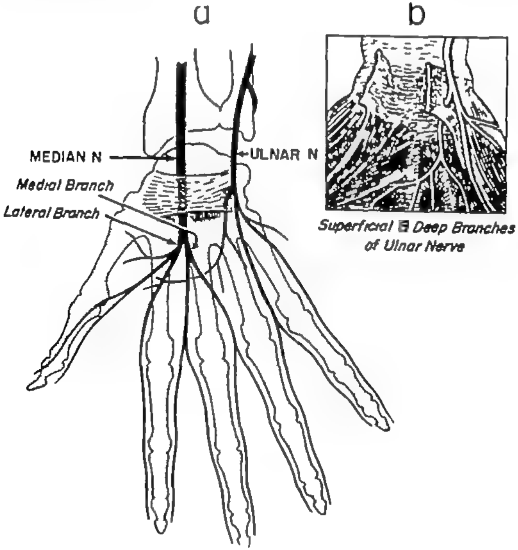

Figure 15 (a) Median and Ulnar nerve distribution on volar surface of hand (b) Division of ulnar nerve into deep and superficial branches.

King[28] found that in the case of a complete ulnar palsy there was some strength in the abductor digiti quinti.

Bjorkesten[29] studied the principle variations of innervation and found three different groups the long finger flexors the thenar muscles and the interossei and lumbricals All the long finger flexors may be innervated by the median nerve and the ulnar nerve may supply the deep flexors of the middle finger or even the index finger He quotes Highet s,[30] investigation of the thenar muscles where twenty complete median nerve lesions were studied

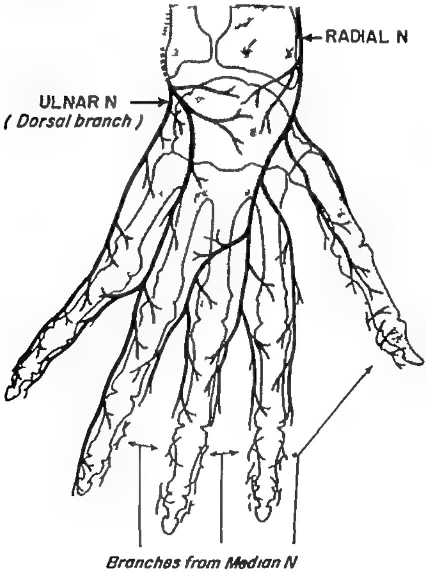

Figure 16. Dorsal distribution of nerves of hand.

and it was found that the ulnar nerve innervated the flexor pollicis brevis in no less than sixteen cases the opponens pollicis in fourteen and the abductor pollicis brevis in two The interossei and lumbricals offer a great degree of variation and when studying 152 cases of ulnar palsy he classified the lesions into various types as follows

Type	0	All lumbricales supplied by the median nerve (7%)
Type	I	Lumbricale IV supplied by ulnar nerve (10%)
Type	II	Lumbricale III–IV supplied by ulnar nerve (11%)
Type	III	Lumbricale I–IV supplied by ulnar nerve (21%)

It is possible that these anomalous innervations to the intrinsic muscles are not due solely to anomalous insertions of nerves but may be due to communications between the median and ulnar nerve in the forearm[31]

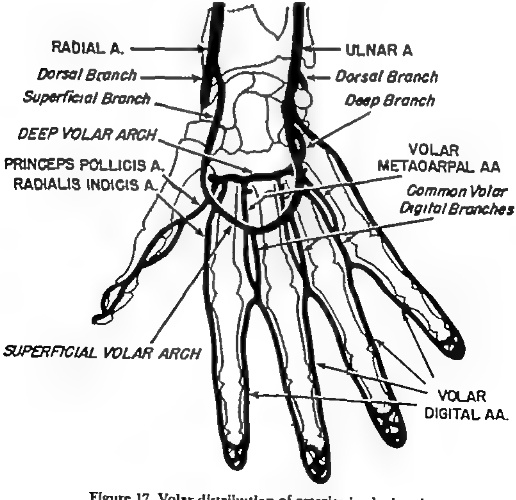

Figure 17 Volar distribution of arteries in the hand.

The *radial nerve* enters the forearm between the brachialis and brachioradialis muscles just anterior to the lateral epicondyle of the humerus and then divides into the superficial and deep branches The superficial branch passes underneath the brachioradialis to descend to the wrist where it pierces the deep fascia and supplies sensation to the dorsum of the hand (Fig 16) The deep branch of the radial nerve winds between the planes of the supinator muscle and passes down the forearm as the dorsal interosseous nerve supplying the extensors of the thumb and index finger The brachioradialis long extensors of the fingers extensor carpi radialis longus and brevis extensor digiti quinti and extensor carpi ulnaris are supplied by the radial nerve in the arm

BLOOD VESSELS

The *brachial artery* passes into the forearm under the lacertus fibrosis in the groove formed by the brachioradialis and pronator teres where it divides into the radial and ulnar artery The *radial artery* passes under the brachioradialis for a short distance and in the region of the wrist is quite superficial covered only by skin and fascia It winds around the radial surface of the wrist beneath the tendons of the abductor pollicis longus and extensor pollicis longus and brevis to pass between the two heads of the first dorsal interosseous muscle into the palm of the hand and crosses the metacarpal bones to unite with the deep branch of the ulnar artery thus forming the deep volar arch (Fig 17) Just above the wrist it gives off the superficial volar branch which passes forward over the muscles of the ball of the thumb and anastomoses with the end of the ulnar artery forming the superficial volar arch which lies between the palmar fascia and the flexor digitorum sublimis tendon The *ulnar artery* passes under the median nerve and flexor digitorum sublimis and descends to the wrist under the flexor carpi ulnaris muscle It becomes quite superficial in the lower third of the forearm and lies between the flexor carpi ulnaris tendon and the flexor digitorum sublimis It crosses over the transverse carpal ligament and curves to meet the superficial volar branch of the radial artery to form the superficial volar arch Just beyond the pisiform bone it gives rise to the deep volar branch which passes with the deep branch of the ulnar

nerve to reach the volar surface of the metacarpals and anastomose with the radial artery forming the deep volar arch The superficial volar arch gives off *common volar digital arteries* which pass to the web spaces of the fingers to divide into the proper volar digital arteries for the index middle ring and little fingers The deep volar arch gives off the *princeps pollicis* from the radial side of the arch just as the radial artery passes through the first dorsal interosseous muscle This passes between the first dorsal interosseous and the adductor pollicis along the ulnar side of the first metacarpal bone to the base of the first phalanx where it divides into two branches which supply the volar surface of the distal half of the thumb Just ulnar to this the *radialis indicis artery* is given off which runs along the radial side of the index finger to its extremity From the remainder of the deep volar arch are given

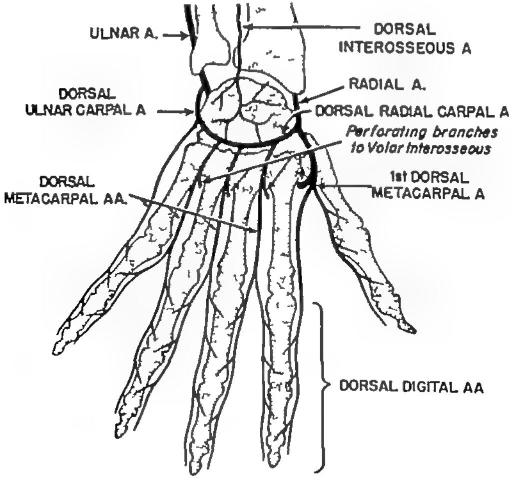

Figure 18 Dorsal distribution of the arteries in the hand

off the three *volar metacarpal arteries* which pass along the inter osseous muscles to the clefts of the finger where they anastomose with the common digital branches of the superficial volar arch.

The dorsum of the hand is supplied by a dorsal arch formed by branches from the radial and ulnar arteries called the dorsal ulnar carpal and dorsal radial carpal arteries which anastomose and give off *dorsal metacarpal arteries* (Fig 18) These run in the metacarpal interspaces as common digital branches for adja cent surfaces of the index middle ring and little fingers. Just as the radial artery plunges through the snuff box to supply the palm of the hand it gives off the *first dorsal metacarpal* which supplies the adjacent sides of the thumb and index fingers. The dorsal arch also is supplied by a longitudinal branch coming from the dorsum of the forearm as a continuation of the dorsal inter osseous artery and a dorsal branch of the volar interosseous artery

The blood supply of the tendons is relatively sparse. Outside the tendon sheaths it arrives from the musculotendinous junction and from the loose paratenon Inside the tendon sheaths, it comes from the tendon insertions and from points of reflection of the synovial sheath on to the tendons at the proximal and distal ends of the sheaths The vessels within the tendon lie in the inter fascicular connective tissue parallel with the collagen bundles and connect through transverse branches Only in the flexor digitorum profundus tendon at the level of the proximal and distal interphalangeal joints are there vertical vascular loops Brockis,[22] believes this may be related to the fact that this tendon is flexed to a greater degree than others at these points and that this arrange ment prevents vascular obstruction No blood vessels are present within the collagen bundles

Conway and Stark,[23] studied the arterial vascularization of the skin of the hand and found three distinct zones of abundant vascularity in the thenar and hypothenar areas and the soft tissues of the palm distal to the palmar flexion creases. The central area of the palm contains a triangular zone which has poor blood supply a fact which may explain poor healing or necrosis when such skin is undermined

LYMPHATICS

The superficial collecting lymphatics of the fingers continue laterally to the base of the fingers where they pass through the interdigital cleft to reach the dorsum of the hand[24] The lymphatic trunks of the palm pass in four directions inferiorly into the web space of the finger to ascend on the dorsum of the hand laterally and medially around the border of the hand to unite with the lymphatics on the dorsum of the hand superiorly toward the anterior surface of the forearm

The collecting trunks of the dorsum of the hand continue upward along the posterior surface of the forearm and incline toward their adjacent borders of the forearm just above the wrist. The lateral and medial collecting trunks turn around their adjacent borders of the forearm and continue up the arm alongside the anterior collecting trunks to terminate in the axillary nodes in the axillary vein group and in the central group A few of the lateral collecting trunks in the upper part of the arm course along the cephalic vein and delto-pectoral sulcus to terminate in the subclavicular or supraclavicular nodes

The deep lymphatics begin in the fingers continue along the digital vessels and course along the posterior interosseous and palmar arches up the forearm accompanying the large vessels such as the ulnar radial anterior and posterior interossei Each of these blood vessels is accompanied by two lymph trunks which anastomose frequently

In the arm these vessels course along the brachial and radial arteries and terminate in the axillary lymph nodes chiefly in the axillary vein group and the central group

FLEXION CREASES

In areas where there is flexion of the joints of the fingers, the skin superficial and deep fascia of the hand blend to form flexion creases (Fig 19) The *distal digital* crease is slightly proximal to the distal interphalangeal joint the *middle digital* crease often is double and is just below the proximal interphalangeal joint the *proximal digital* crease lies proximal to the mid point of the proximal phalanx There are two transverse palmar creases The

off the three *volar metacarpal arteries* which pass along the inter osseous muscles to the clefts of the finger where they anastomose with the common digital branches of the superficial volar arch

The dorsum of the hand is supplied by a dorsal arch formed by branches from the radial and ulnar arteries called the dorsal ulnar carpal and dorsal radial carpal arteries which anastomose and give off *dorsal metacarpal arteries* (Fig 18) These run in the metacarpal interspaces as common digital branches for adja cent surfaces of the index, middle ring and little fingers Just as the radial artery plunges through the snuff box to supply the palm of the hand it gives off the *first dorsal metacarpal* which supplies the adjacent sides of the thumb and index fingers The dorsal arch also is supplied by a longitudinal branch coming from the dorsum of the forearm as a continuation of the dorsal inter osseous artery and a dorsal branch of the volar interosseous artery

The blood supply of the tendons is relatively sparse. Outside the tendon sheaths it arrives from the musculotendinous junction and from the loose paratenon Inside the tendon sheaths it comes from the tendon insertions and from points of reflection of the synovial sheath on to the tendons at the proximal and distal ends of the sheaths. The vessels within the tendon lie in the inter fascicular connective tissue parallel with the collagen bundles and connect through transverse branches. Only in the flexor digitorum profundus tendon at the level of the proximal and distal interphalangeal joints are there vertical vascular loops Brockis [22] believes this may be related to the fact that this tendon is flexed to a greater degree than others at these points and that this arrangement prevents vascular obstruction No blood vessels are present within the collagen bundles.

Conway and Stark [23] studied the arterial vascularization of the skin of the hand and found three distinct zones of abundant vascularity in the thenar and hypothenar areas and the soft tissues of the palm distal to the palmar flexion creases. The central area of the palm contains a triangular zone which has poor blood supply a fact which may explain poor healing or necrosis when such skin is undermined

distal palmar crease begins just proximal to the fifth metacarpophalangeal joint and extends regularly across the distal portion of the palm in a somewhat curved line ending between the index and middle fingers The *proximal palmar crease* begins on the radial side of the palm just behind the metacarpophalangeal joint of the index finger and extends ulnarly across the palm ending in the hypothenar eminence There also is present a curved *thenar crease* which begins with the proximal palmar crease and curves around the base of the thenar eminence to lie in the midline between the thenar and hypothenar eminences There are usually two *wrist creases* on the flexor surfaces of the wrist which accurately follow the line of the wrist joint.

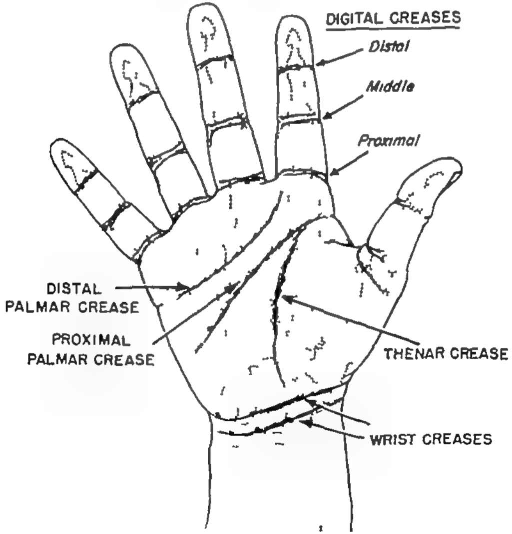

Figure 19 Important flexion creases of the hand

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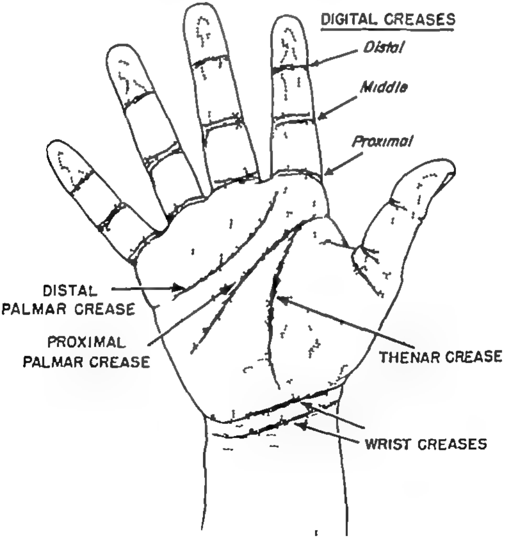

Figure 19 Important flexion creases of the hand.

CHAPTER 2

EMBRYOLOGY

Little has been added to knowledge of the embryology of the upper extremity since the classic work of Bardeen and Lewis at the turn of this century.[1] Their work was the main source of reference in the preparation of this chapter. The development of each system will be briefly discussed following which the hand of an 8½ week old fetus will be described.

ARM BUD

At slightly less than three weeks of age, the site of the future arm bud may be seen as a proliferation of mesenchymal cells in the somatopleure at the level of the eighth myotome (Fig. 20). During the third week the arm bud develops by the growth of mesenchymal cells and embryonic blood vessels and lies opposite the fifth cervical to the first thoracic intervertebral disks pointing in a caudal direction. The end of the bud flattens and constrictions develop at the future elbow and wrist sites during the fourth week (Fig. 21). At the same time it bends at the elbow, which points laterally with the palm lying against the trunk. During the next two weeks the hand bud segments into digits while the entire upper limb rotates ninety degrees outward and forward on the shoulder girdle so that the pre-axial or radial border is directed inward and the flexor surface is turned downward. By the eighth week the hand and arm are complete.

BONES AND JOINTS

At the 4½ week stage the center of the arm bud is made up of condensed mesenchymal tissue which takes a deeper stain than the surrounding tissue. This is to be the future skeletal system of the arm. It is a continuous mass of cells from the hand to the future scapula, a quadrilateral mass at the level of the fourth and fifth cervical disks (Fig. 22).

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By the fifth week cartilage has made its appearance in the various portions of the arm skeleton The humerus is still continuous with the scapula and is composed of a core of hyaline cartilage surrounded by very thick perichondrium It is continuous with the radius and ulna and no evidence of a joint surface or cavity is seen The core of the radius and ulna similarly is composed of hyaline cartilage surrounded by thick perichondrium which continues into the condensed tissue at either end of the bone The hand plate is continuous with the distal ends of the radius and ulna and similarly is composed of condensed

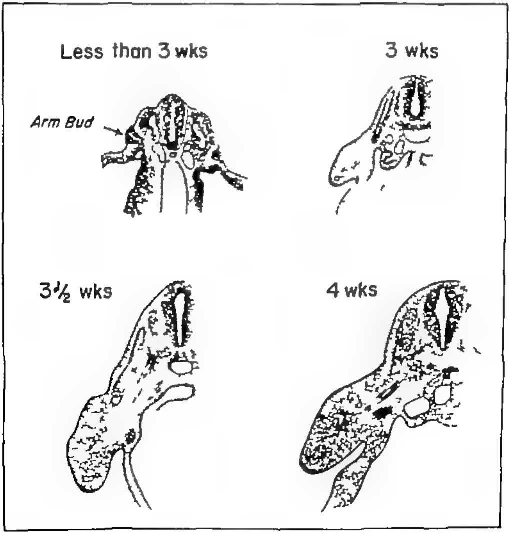

Figure 20 Cross-section of human embryos of various ages demonstrating arm bud development (after Lewis)

mesenchymal tissue There are several centers of increased condensation corresponding to various carpal bones Extending from the carpus are five masses of condensed tissue which are the future fingers with no segmentation as yet into the metacarpals and phalanges

During the sixth week the humerus is larger and longer but is still connected to the scapula by condensed mesenchymal tissue The thick perichondrium of the humerus is continuous with the head of the scapula and forms the future capsular ligament The

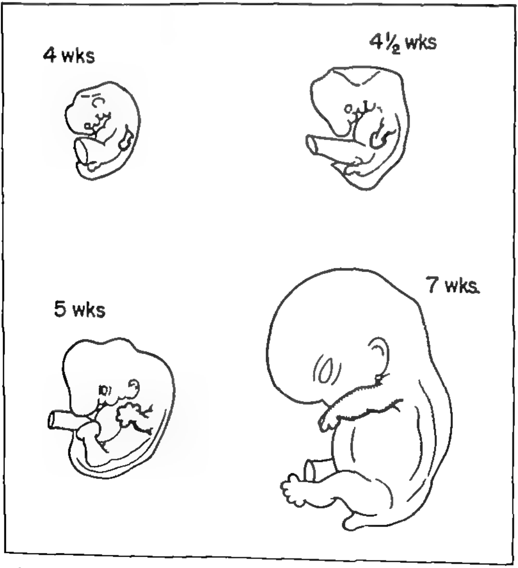

Figure 21 Diagrams of human embryos demonstrating the development of the upper extremity from the fourth to the seventh week of fetal life (after Bardeen and Lewis)

By the fifth week cartilage has made its appearance in the various portions of the arm skeleton The humerus is still continuous with the scapula and is composed of a core of hyaline cartilage surrounded by very thick perichondrium It is continuous with the radius and ulna and no evidence of a joint surface or cavity is seen The core of the radius and ulna similarly is composed of hyaline cartilage surrounded by thick perichondrium which continues into the condensed tissue at either end of the bone The hand plate is continuous with the distal ends of the radius and ulna and similarly is composed of condensed

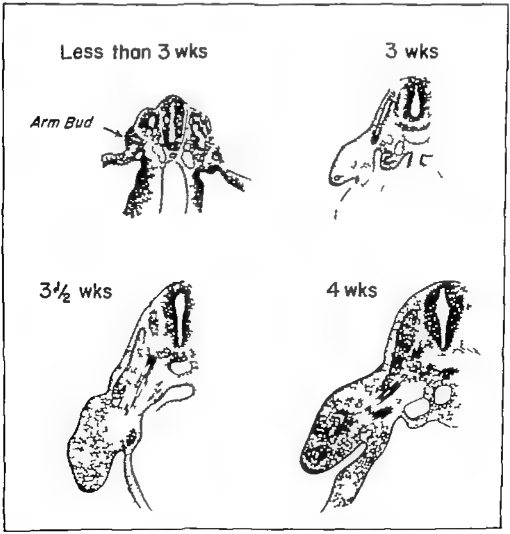

Figure 20 Cross-section of human embryos of various ages demonstrating arm bud development (after Lewis)

ited from its neighbor by an area of condensed mesenchymal tissue

By the seventh week the various structures have become larger and definite capsular ligaments are forming around the joints but as yet no definite joint cavity exists in the arm The carpal bones are more definitely placed in their usual position however they are still embedded in a mass of condensed mesenchymal tissue Five metacarpals are present as cartilaginous structures surrounded by thick perichondrium and there are two rows of phalanges present in all the digits These consist of an area of cartilage surrounded by very thick perichondrium which is con tinuous with the metacarpals There is an enlarged condensed mass of tissue at the tip of each digit from which will form the future distal phalanges of the second third fourth and fifth fingers

The development of the joints of the fore limb have been re investigated by Haines[2] As chondrification occurs the adjacent bone anlage are connected by masses of condensed blastema called interzones The fibrous capsules develop as condensations of mesenchymal blastema and cut off a portion of general mesen chyme now known as the *synovial mesenchyme* and a portion of the condensed perichondrium now known as *intra capsular peri chondrium* The middle layer of the interzone becomes looser in character at about the twenty first millimeter stage and becomes continuous with the synovial mesenchyme Liquefaction of this loose layer of interzone and inner layer of synovial mesenchyme takes place at about thirty millimeters giving rise to a joint cavity The future shape of the joint cavity is well established early in the fetus and is not dependent on embryonic motion The synovial mesenchyme gives rise to the synovial and sub-synovial tissues as well as all intra-capsular structures such as ligaments tendons and fibro-cartilages

The carpal bones ossify from a single center and during the first year ossification begins in the hamate and the capitate The remaining bones ossify as follows triquetrum third year lunate and greater multangular fifth navicular sixth lesser multangular eighth and pisiform twelfth

The metacarpal bones ossify from two centers one from the

ulna and radius are two separate cartilaginous structures The perichondrium of both is continuous with the distal end of the humerus forming the beginning of the joint capsule of the elbow The olecranon is well developed and consists mostly of cartilage the coracoid process consists mainly of condensed tissue The radius and ulna merge into the hand plate which is now assuming a definite hand structure The carpus consists of condensed tissue in which lie embedded the various cartilages the greater and lesser multangulars the os capitate the hamate and the navicular semilunar triquetrum and pisiform The metacarpus consists of five slender cartilages surrounded by a thick tissue layer of perichondrium The first metacarpal cartilage is only about half the length of the others The proximal phalanges are present as short slender cartilages deeply embedded in condensed tissue at the tips of the four ulnar metacarpals The tip of each of these digits is composed of condensed mesenchymal tissue There are no joint cavities between the cartilages of the hand each one being separ

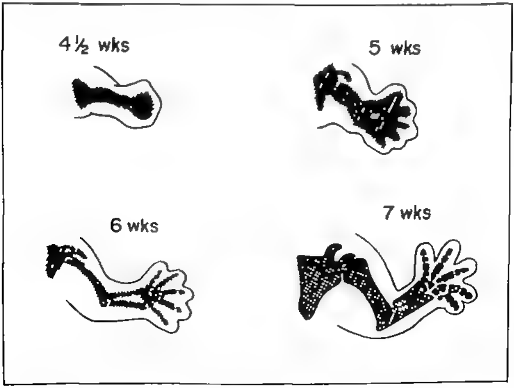

Figure 22. Development of the skeletal system of the upper extremity (after Lewis)

the proximal extremities during the third and fourth years The epiphyseal plates close between the eighteenth and twentieth years

Acheson [4] devised a new formula for assaying skeletal maturity based on the development of the epiphyses of the radius ulna and remaining bones of the wrist hand and fingers

MUSCLES

The skeletal core of the arm is surrounded by a mass of tissue which at the four week level shows no sign of splitting into separate muscle masses (Fig 23) The ends of the brachial plexus are beginning to penetrate this pre muscle sheath of cells along the proximal portion of the humerus and in many other places it is separated from the skeletal core by blood vessels Toward the distal end of the arm the sheath merges into the more primitive mesenchymal tissue

By the fifth week definite muscles are forming from the pre muscle sheath The triceps muscle extends along the posterior surface of the humerus from the scapula to the ulna and there are indications of three heads being present The musculospiral nerve passes through it and gives off branches The biceps and coracobrachialis lie along the median side of the humerus and the two heads of the biceps can be clearly seen The distal end of the biceps blends with the brachialis and the flexor mass of the forearm and the coracobrachialis is attached to the humerus by condensed mesenchymal tissue. The musculocutaneous nerve pierces this group of muscles giving branches to it The brachialis muscle is closely attached to the distal one half of the humerus and blends intermittently with the overlying biceps muscle It inserts into the ulna by condensed tissue closely associated with the flexor mass of the forearm It is supplied by the musculocutaneous nerve

The flexor muscle mass of the forearm forms a thick layer over the median surface of the ulna radius carpus and meta carpus There are approximately two layers present (1) a super ficial layer lying in the proximal region of the forearm which will form the future flexor carpi radialis flexor sublimis digi torum pronator teres and palmaris longus muscles (2) the deep layer which is closely attached to the perichondrium of the

body and one from the distal extremity of the second third fourth and fifth bones and from the base of the first metacarpal bone Since the thumb metacarpal ossifies in the same manner as the phalanges it is felt by some anatomists that the thumb is made up of three phalanges with no metacarpal bone Ossification centers for the bodies of the metacarpal bones arise about the eighth or ninth week of fetal life During the third year of life the distal extremities of the metacarpals of the fingers and the base of the thumb begin to ossify The epiphyses of the meta carpal bones unite during the twentieth year

The phalanges similarly ossify from two centers one from the body and one from the proximal extremity Ossification begins in the body about the eighth week of fetal life and in

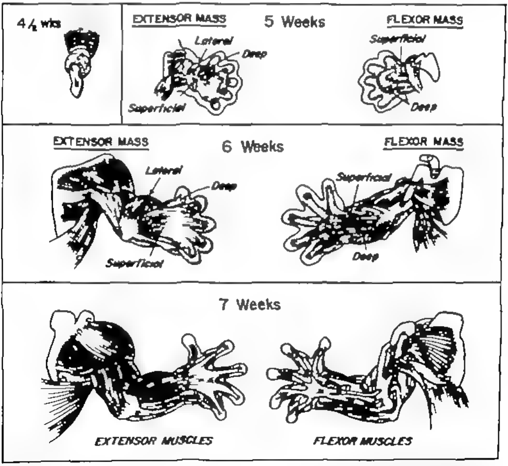

Figure 23 - Muscle development in the upper extremity showing the rapid change from the pre muscle sheath of four and a half weeks to the almost complete organization of seven weeks (after Lewis).

passes around the dorsum of the humerus decreasing rapidly in size and ending in the pre muscle sheath near the distal end of the humerus This is to be the future radial nerve The ventral division is divided into two parts From the outer part comes the suprascapular nerve and the rest splits into the musculocutaneous and the outer head of the median nerve The inner cord terminates in the ulnar nerve which runs into the pre muscle sheath along the median side of the humerus as far as the beginning of the ulna

By the sixth week the arm migrates somewhat posteriorly and the entire brachial plexus is pulled caudally and posteriorly By this time it is divided into the various cords much more clearly than in the previous stages There is nothing peculiar about the distribution of the remaining nerves of the plexus either motor or sensory from that which is present in the adult

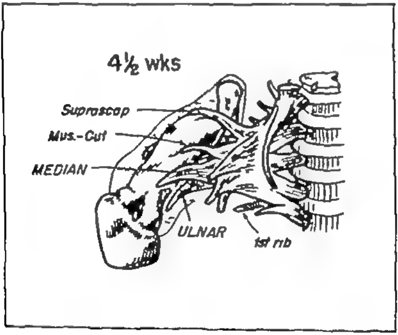

Figure 24 The brachial plexus at four-and-a half weeks (after Lewis)

ARTERIES

Several lateral aortic branches grow into the early limb bud uniting in a capillary plexus (Fig 25a) In the five millimeter human embryo there is only one arterial stem in the forearm called the *interosseus artery* which extends to the end of the digit

forearm and hand which will ultimately form the flexor profundus digitorum flexor pollicis longus flexor carpi ulnaris and pronator quadratus muscles There are already branches of the median and ulnar nerves present in this flexor mass

The extensor mass of the forearm is farther advanced than the flexor and can be differentiated into three groups The first group is the largest and most superficial extending from the lateral condyle of the humerus to the proximal ends of the digits covering the ulnar two-thirds of the forearm From it will arise the extensor communis digitorum extensor carpi ulnaris and extensor minimi digiti The second or lateral group occupies the proximal portion of the radial side of the forearm arising in connection with the first group from the lateral condyle of the humerus It passes distally along the radius and will become the brachioradialis and extensor carpi radialis longus and brevis The third or deep group arises beneath the first group and its fibers pass toward the radial side of the forearm passing underneath the first group and over the second group ending in the condensed tissue of the first and second digits. This will ultimately form the abductor pollicis longus extensor pollicis brevis extensor pollicis longus and extensor indicis proprius Branches of the radial nerve are present in these developing muscles

During the next two weeks the muscles attain their adult form and position The proximal portions develop before the distal portions emerge from the mass of condensed mesenchymal tissue at the growing tips of the fingers As each muscle develops its nerve is present.

NERVOUS SYSTEM

Spinal nerves grow out from the cord to approximately the root of the arm bud at the five millimeter stage By the fourth week or seven millimeter stage they begin to descend into the arm At this stage the brachial plexus is fairly well developed from the ventral divisions of the fourth fifth sixth seventh and eighth cervical and the first thoracic nerves (Fig 24) They form a continuous sheath of nerve tissue in which only indications of the three cords can be distinguished On reaching the arm bud they split into dorsal and ventral divisions The dorsal division

gives off a distal branch which anastomoses with the superficial volar arch At the elbow an anastomotic branch between the brachial artery and the superficial brachial artery becomes enlarged and the proximal portion of the superficial brachial artery atrophies (Fig 25d) This anastomatic branch together with the distal portion of the superficial brachial artery becomes the *radial* artery

VEINS

A primitive capillary plexus of the limb bud gives rise to a peripheral *border vein* which serves as an early drainage channel The border vein originally opens into the dorsal wall of the post cardinal system but as the heart shifts caudally it drains by a ventral connection into the precardinal (internal jugular) vein From the ulnar portion of the border vein develops the *subclavian, axillary* and *basilic* veins The radial extension of the border vein atrophies partly but from it arises the *cephalic vein* which anastomoses at first with the external jugular but ultimately into the axillary vein

SKIN AND SKIN APPENDAGES

The embryonic ectoderm is originally a single sheet of cuboidal cells but by the fifth week it adds a second layer During the third and fourth months the epidermis is three layered After the fourth month the epidermis becomes highly stratified and resembles adult skin with the four layers of *stratum corneum lucidum granulosum* and *germinativum*

At ten weeks there is a thickened area of epidermis on the dorsum of each digit which eventually grows proximally toward the distal interphalangeal joint. This plate splits giving origin to a *proximal nail fold* which is continuous on each side with the shallow *lateral nail fold* This primitive nail fold undergoes some local cornification but the true nail develops within the nail *matrix* in the lunula area During the fifth month specialized keratin fibrils differentiate in the matrix and go on to develop the nail which reaches the tip of the digit about one month before birth

The hair begins to develop about the fourth month and *lanugo* hairs are developed by the seventh month

where it breaks up into a digital plexus of vessels (Fig 25b) At a later stage a *median artery* branches off the brachial artery and unites with the digital plexus The previous connection of the interosseus artery with the digital plexus disappears (Fig 25c) The subsequent development has been clarified by Singer[*] In embryos of about eighteen millimeters the *a. ulnaris* arises from the brachial artery and unites distally with the median to form the superficial carpal arch which give off digital branches

In embryos twenty-one millimeters long the *a brachialis superficialis* develops in the axillary region and traverses the medial surface of the arm and runs diagonally from the ulnar to the radial side of the forearm to the posterior surface of the wrist. There it divides over the carpus into branches for the dorsum of the thumb and index finger

Finally three changes occur When the embryo reaches the length of about twenty three millimeters the median artery undergoes retrogression becoming a small slender structure now called the *artery of the median nerve* The superficial brachial artery

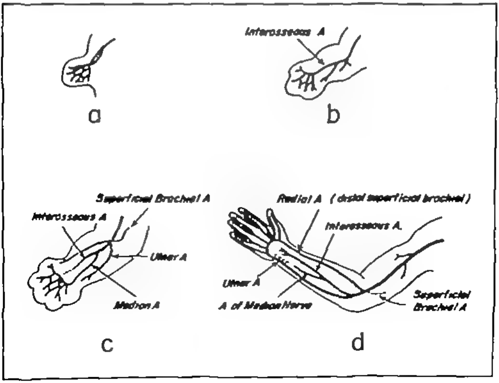

Figure 25 Development of the vascular system of the upper extremity

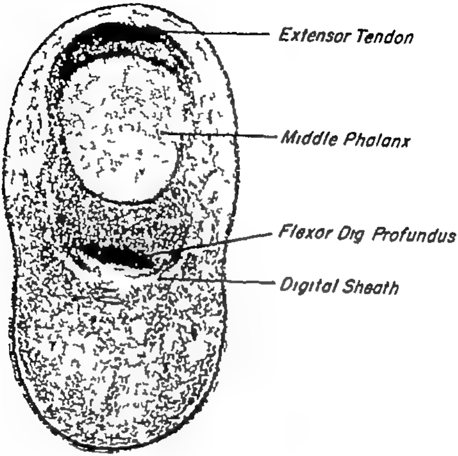

Figure 27 Same hand at level of middle phalanx

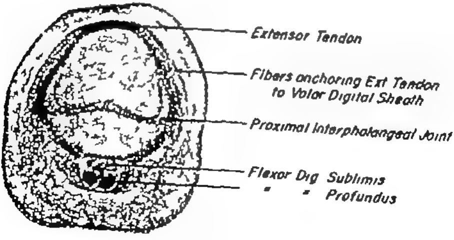

Figure 28 Same hand at level of proximal interphalangeal joint.

The sebaceous glands first appear about the fifth month from the epithelial sheath of the hair follicles Sweat glands begin to develop by the fourth month and by the seventh month they are fairly well developed

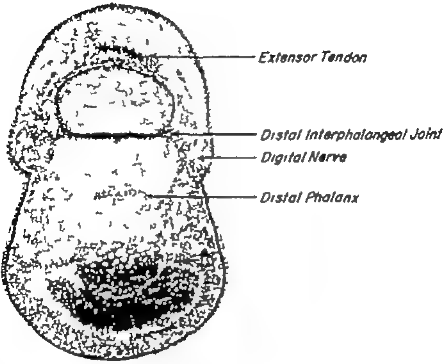

Figure 26 Cross-section of 8½ week fetal hand at level of distal interphalangeal joint.

AN 8½ WEEK FETAL HAND

Cross-sections of a fetal hand aged 8½ weeks reveal an almost exact replica of the adult. The distal phalanx (Fig 26) is almost completely formed and the distal interphalangeal joint is developing At the level of the middle phalanx (Fig 27) the extensor apparatus and flexor digitorum profundus with its sheath are discernible The proximal interphalangeal joint is developing and the separation of the flexor digitorum profundus and sublimis has taken place (Fig 28) The extensor mechanism appears to be anchoring to the joint capsule and flexor sheath as pointed out by Kaplan [6] At the level of the proximal phalanx (Fig 29) the flexor digitorum profundus lies volar to the developing

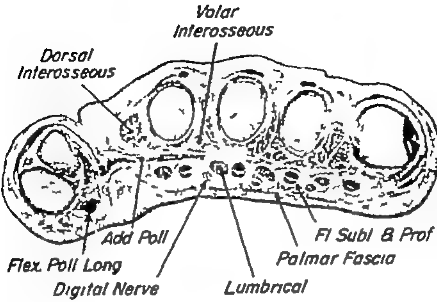

Figure 81 Same hand at level of distal palm.

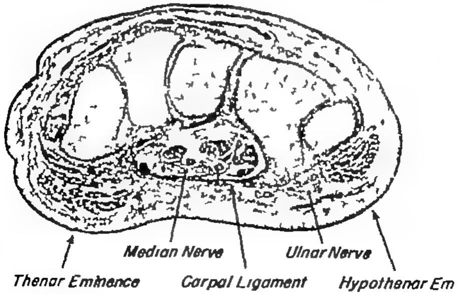

Figure 82 Same hand at level of wrist

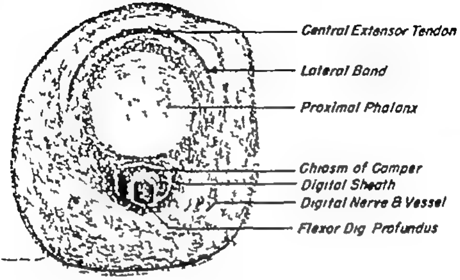

Figure 29 Same hand at level of proximal phalanx.

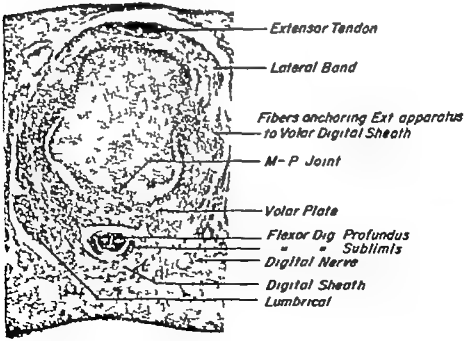

Figure 30 Same hand at level of metacarpophalangeal joint.

PART II

INFECTION

chiasm of Camper The digital sheath appears much thicker than in other levels Hinrichsen [7] studied tendon sheath development and found that this thickening of the sheaths at the site of future annular ligaments occurs before any flexion has taken place in the fingers and must be due to a tissue pre-determination rather than a response to motion

At the metacarpophalangeal joint (Fig 30) the flexor digitorum profundus pierces the flexor digitorum sublimis The tendon sheath is firmly attached to the developing volar plate of the anterior joint capsule The extensor mechanism is anchored to these two structures

In the distal palm (Fig 31) and wrist (Fig 32) all the adult structures can be visualized

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CHAPTER 3

GENERAL PRINCIPLES

Before chemotherapy and antibiotics surgery of the hand was mainly the treatment of hand infections with the classic treatises being written by Kanavel [1] and Iselin [2] Treatment of hand infection was emphasized in medical schools and graduate programs However with the advent of chemotherapy and antibiotics there was a decline in the incidence of hand infections throughout the world Experience at the Boston City Hospital paralleled this trend and since antibiotics became available lymphangitis and deep fascial space infections decreased 80 per cent and suppurative tenosynovitis 75 per cent [3] As a consequence the teaching of hand infections has been minimized and the average doctor begins practice today with very little knowledge of their correct treatment

This is a dangerous situation for obvious reasons Even if major hand infections are becoming scarcer they demand the same expert care that previously was given them Besides the protective action of antibiotics appears to be on the wane and more and more hand infections are seen in Hand Clinics

The epidemiology of boils and infected hands in a factory population was studied from 1943-47 [4] An increased incidence of these infections over the years was observed so that by the final year of the study it was double that in the first year Even if serious hand infections were prevented the minor infections were incapacitating, a situation which will be prevalent for many years to come Wilkes [5] studied a large series of hand infections and despite the fact that the great majority were not serious the average time loss from work was twenty days Attempted prevention of such injuries by use of protective gloves and improvement of first-aid treatment was not very effective

These introductory remarks emphasize that hand infections are still important diseases and the principles of proper treatment

with [illegible] one should remember that when this is [illegible] [illegible] wounds and infections seem to heal slowly.

The aftercare of each wound is designed to prevent superimposed infection. Debridement of dead tissue is performed whenever it occurs, and clean granulation tissue is skin-grafted as soon as possible to prevent fibrosis. The subsequent changes of dressings are performed under aseptic conditions using sterile instruments and surgical face masks.

Physiotherapy in the form of active and passive motion is instituted early to prevent ankylosis of the finger joints. If a hand has been immobilized for any length of time, physiotherapy also is directed to the elbow and shoulders. In the older age group these joints may become ankylosed within a relatively short period and the subsequent disability may outweigh the hand disability.

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should be known by practicing physicians and definitely included in the medical school curriculum

Correct treatment of infections of the hand demand a knowledge of the causative organism and its anatomical localization (these will be discussed in separate chapters) In addition there are some general principles of treatment which should not be forgotten

Treatment must be instituted as early as possible to prevent spread of infection and irreversible sequelae such as necrosis of tissue and permanent fibrosis

All operations are carried out in a bloodless field under general or regional anesthesia with good lighting and assistance If the infection is limited to a distal part of the finger such as a felon or paronychia, local anesthesia may be used but extreme care should be taken since occasional cases of gangrene of the finger have been reported

The function of drains is to keep incisions open They should never plug the wound and prevent a free flow of exudate They should never extend into tendon sheaths or joint spaces Vaseline strips or small rubber strips are the usual drains used In fingers, it is better to use small rubber strips by choice because of lack of space Drains usually are removed in forty-eight hours

Immobilization of the part is essential for recovery This may be obtained by a massive dressing in the early stages of acute infection which is later replaced by a plaster-of Paris splint. When the hand is immobilized for more than a day it is placed in the position of function the wrist in twenty degrees dorsiflexion the finger joints in slight flexion the thumb in abduction and opposition with its interphalangeal joint slightly flexed If the finger joints become stiff in this position it still is possible to have suitable hand function with only a few degrees motion in each of the joints If the fingers have been held extended and become stiff the hand is useless

Systemic diseases are searched for in all cases with particular emphasis on diabetes lues or the various bleeding diatheses The patient's nutrition is maintained in as normal a state as possible with particular attention to correction of anemia Vitamin C deficiency and protein deficiency Since many patients are treated

After reviewing much of the literature in this field Finland[4] reports Combinations of antibiotics have been widely used clinically for infections other than tuberculosis chiefly for their additive or possibly synergistic effects and particularly in staphylococcal infections There are as yet no reports of controlled studies from which the effect of such antibiotics on emergence of resistance can be evaluated

MICROCOCCUS AUREUS (STAPHYLOCOCCUS AUREUS)

This group of organisms which produces toxins with necrotizing hemolytic and leukocidic properties is the most common cause of hand infections[5] Coagulase positive organisms are most apt to be pathogenic, but there is some evidence that alpha hemolysin production similarly correlates with virulence[6]

Many strains inhibit the action of penicillin There may be two mechanisms for this inhibitory phenomenon production of penicillinase and/or the elaboration of an essential growth factor whose production in the sensitive strains is blocked by penicillin The entire problem of the relationship of resistance of staphylococcus to antibiotic agents has been reported as follows

The percentage of penicillin resistant staphylococci isolated from patients in large hospitals in many countries has increased steadily in the past few years so that now nearly three fourths of all strains are highly resistant to penicillin

Penicillin resistant strains are found not only in suppurative lesions under treatment with this antibiotic but also in the noses and throats in similar proportions from patients in the same hospital who are not receiving penicillin—and frequently in the feces of such patients

The percentage of penicillin resistant staphylococci increases markedly during the period of hospitalization both in patients who receive penicillin in the hospital and in those who do not although penicillin therapy results in somewhat earlier and more frequent appearance of the resistant strains

The hospital staff and personnel carry staphylococci of the same bacteriophage types as the patients and a similar proportion are resistant to penicillin

Phage typing of staphylococci from patients and staff indicates

CHAPTER 4

BACTERIOLOGIC FACTORS

As a basis for correct chemotherapy the causative organism should be determined in every case by use of aerobic and anaerobic cultures These cultures should be repeated periodically to detect changes in the bacterial flora consequent to secondary contamination or antibiotic therapy

Exposure of bacteria to an antibiotic agent may lead to the *development of resistant strains to the same antibiotic* and, because of the indiscriminate use of various antibiotics by the medical profession this problem is increasing Meleney and Johnson[1] found that 17 8 per cent of coagulase positive Staphylococcus aureus strains were resistant in 1947-48 whereas in 1951 this resistance rose to 43 per cent. Another example of this is a report by Altemeier *et al*[2] who found that during the years 1942-43 96 per cent of the virulent hemolytic micrococci were sensitive to penicillin whereas in 1955 only 57 per cent remained sensitive to the antibiotic. In vitro sensitivity tests are valuable in discovering such resistance so that a proper choice of antibiotic may be made

When more than one organism is present in an infection a mixture of antibiotics may be used as determined by culture and sensitivity studies However caution must be taken in administering these combinations since some antibiotics are synergistic and some antagonistic to each other In general synergism exists between two members of the bactericidal antibiotics (penicillin bacitracin streptomycin polymyxin B neomycin) or between two members of the bacteriostatic group (tetracycline chlortetracycline chloromycetin) Antagonism may occur when a member of the bactericidal group is administered with one of the bacteriostatic group[3] As yet, there appears to be no definite knowledge that such combinations of antibiotics are effective

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The hospital staff and personnel carry staphylococci of the same bacteriophage types as the patients and a similar proportion are resistant to penicillin

Phage typing of staphylococci from patients and staff indicates

that the organisms are acquired by crossinfection from other patients and from the hospital personnel (chiefly the latter)

Penicillin resistant staphylococci are much less frequent among outpatients than among inpatients among the outpatients the incidence is related to the amount of previous penicillin treatment or of previous hospitalization or both

The incidence of strains resistant to penicillin among the general population is still lower than that among outpatients and this too is related to previous treatment and hospitalization At the time of admission to hospitals, patients have a higher carrier rate of penicillin resistant staphylococci than people in the community at large

When studies have been carried out in areas where very little antibiotic therapy is used, resistant staphylococci from infected lesions or from carriers are generally infrequent.

Resistance of the staphylococci is generally much lower to the tetracycline antibiotics than to penicillin but in hospitals where they have been used very extensively the incidence may approach that of penicillin resistant strains during periods of intensive use Usually tetracycline-resistant staphylococci are about half as frequent as the penicillin resistant ones

Erythromycin resistant strains of staphylococci rapidly appear in hospitals where that antibiotic is used both the degree of resistance and the incidence of resistant strains appear to increase with such use even more rapidly than with earlier antibiotics, and the number of erythromycin resistant strains within a brief period may reach or even exceed that of penicillin resistant strains during periods of intensive use

The incidence of strains resistant to individual antibiotics is related to the extent to which each is used

The frequency with which strains resistant to multiple antibiotics are encountered is similarly related to the extent to which the particular antibiotics in question are used

Increases or decreases in the amounts and intensity with which any given antibiotics are employed my be associated with changes in the same direction in the incidence of staphylococci resistant to those antibiotics

The simultaneous use of antibiotics in combinations has been

recommended as a means of preventing the development of resistant strains of staphylococci Data reflecting the results of combined therapy are scanty but thus far indicate only the possibility of depressing delaying or avoiding the appearance of resistant strains in individual patients there is no evidence as yet that the incidence of resistant strains is reduced by combined therapy

"The increasing occurrence of staphylococcal infections within hospitals and the decreasing effectiveness of the available antibiotics in the treatment of such infections is being widely appreciated and in many hospitals is reaching serious proportions [4]

This organism produces a local pyogenic manifestation such as furuncle or abscess and in addition may spread by blood stream invasion producing either a fulminating or chronic infection In the fulminating type there is a high temperature and pulse rate with profound toxemia The usual systemic infection however runs a chronic course and is accompanied by metastatic abscesses in the lungs kidneys liver spleen heart and bones

Surgical incision with or without excision of necrotic tissue plays the major role in eradicating these infections but antibiotic therapy is necessary For local application bacitracin in concentration of 1 000 units per cc. appears to be of most value For systemic therapy one may choose between penicillin streptomycin or a tetracycline derivative Bacitracin may be used parenterally if the daily fluid intake is at least 2,500 cc.

STREPTOCOCCUS

The classification of this organism depends on antigenic substances and the ability to hemolyze blood Group A beta hemolytic strains produce the great majority of streptococcal diseases in man with occasional strains in group C and G being responsible These three groups produce fibrinolysin desoxyribonuclease hyaluronidase and erythrogenic toxin The non hemolytic streptococci usually are secondary invaders and may produce a chronic disease. The anaerobic strains of streptococcus will be discussed later

The general pattern of such hand infections is a cellulitis with lymphangitis and lymphadenopathy associated with fever and toxic symptoms The organisms may enter the blood stream and metastasize to joints, lungs kidneys spleen liver brain and skin

The endothelial lined cavities (pleura, pericardium peritoneum meninges) also may become involved For hemolytic streptococci penicillin or tetracycline is the antibiotic of choice since at the Boston City Hospital strains of Group A streptococci of even slight resistance to these drugs have not been encountered thus far[7] The non hemolytic organisms may be resistant to this drug and require other antibiotics chosen by sensitivity studies

SYMBIOTIC INFECTION

The combination of microaerophilic non hemolytic streptococcus and hemolytic staphylococcus aureus produces a destructive lesion of the skin and subcutaneous tissue The lesion usually is painful and tender and the gross appearance is quite characteristic. There is an outer zone of erythema (varying from one to two centimeters in width) a sharply defined dark purple middle zone and an inner zone of gangrenous skin The inner margin is only slightly undermined but gradually melts away as the whole lesion spreads centrifugally The purplish area of gangrenous skin often demonstrates a characteristic edema with vesiculation of the overlying epithelium The center of the lesion becomes a granulating ulcer which in time may become bright red and clean The disease continues to spread until the patient dies or the infection is brought under control

The clinical appearance of this lesion is usually sufficiently characteristic to make the diagnosis but a correct bacteriological study is necessary The staphylococcus may be found but it is more difficult to uncover the microaerophilic streptococcus. The disease appears to spread along the lymphatics on the fascia which often is affected for centimeters beyond the clinical gangrene Consequently some authors call this disease necrotizing fasciitis[8]

Treatment is wide surgical excision plus antibiotics which are effective against the causative organism as demonstrated by sensitivity tests The excision should be carried far beyond the zone of gangrene to be sure that the involved fascia is removed. When performing surgical excision Wilson[8] suggests that the skin flaps be lifted off the underlying involved fascia. The involved area is excised completely and the skin flaps returned to their original position In this way he attempts to prevent the tremen

Figure 33A (Top) Symbiotic infection. Compound fracture left thumb five days following injury showing infection advanced to proximal phalanx.

Figure 33B (Middle) Spread of infection from thumb to wrist.

Figure 33C. (Bottom) Infection three weeks following injury

dous skin losses resulting from older methods of treatment

After the skin underlying fascia and any other infected tissue (tendons) are removed the wound is treated locally by a chemical agent (Dakin s solution activated zinc peroxide) an antibiotic agent (bacitracin streptomycin sulfamylon mixtures) or other combinations of antibiotics found useful by sensitivity studies. Systemic chemotherapy has proven of little value although Meleney[8] believes that bacitracin is the drug of choice How ever in clinical experience with three cases during the past several years this has proven to be of no value to the author After the excised area is covered with healthy granulation tissue skin grafting procedures are necessary to cover the existing defect

A tragic experience with this infection is noteworthy

Mr F (BCH 1415518) a fifty nine year old white male sustained a compound fracture of the right thumb while at work. Five days later on entry to the Boston City Hospital the wound which had been sutured elsewhere, appeared as demonstrated in Figure 33A. It was believed that this was a severe pyogenic infection and, accordingly penicillin therapy was instituted and an incision made. The incision revealed no pus and a specimen was sent for culture The infection continued to spread until approximately five days after entry it involved the dorsum and volar aspect of the wrist and lower forearm (Fig 33B) At this time symbiotic infec tion was diagnosed, and bacteriologic studies revealed the presence of enterococci Staph. aureus, Aerobacter aerogenes, Bacillus proteus. Cultures were sent not only to our own hospital laboratory but also to the laboratory of Dr Chester Howe at Boston Uni versity School of Medicine to attempt to uncover microaerophilic streptococcus. Aureomycin was instituted intravenously for approx imately five days. Localized phlebitis developed at the site of each aureomycin infusion Infection continued to spread along the forearm on the volar and dorsal surfaces and into the palm and dorsum of the hand (Fig 33C) The treatment thus far consisted of wide surgical excision but it was decided to try parenteral bacitracin This had to be discontinued in approximately four days when the non protein nitrogen rose to a high level and protein casts were found in the urine. The local agent applied to the excised area was hydrogen peroxide alternating with bacitracin solution At this stage sensitivity studies, performed by Dr Howe

Figure 33D (Top) Skin grafts well healed on left forearm.

Figure 33E. (Middle) Development of infection at site of aureomycin injection right forearm, four weeks after initial injury

Figure 33F (Bottom) Spread of infection in right arm and forearm.

Figure 55G (Top) Further spread of infection to entire right upper extremity

Figure 55H (Bottom) Infection in both groins five months after initial injury

revealed the organisms to be sensitive to a combination of streptomycin and sulfamylon. Following wide excision of the infected area, the wound was dressed with an occlusive dressing under which multiple catheters were applied and through which the streptomycin-sulfamylon mixture could be injected at numerous intervals during the day so that a high concentration of this agent would be present continuously. Using this approach, the infection appeared to be controlled with a complete denuding of the skin and fascia from the elbow down to the metacarpophalangeal joints of the fingers involving many of the extensor and flexor tendons. The involved area began to granulate, and split thickness skin grafts were applied to the granulating areas (Fig. 33D).

Approximately four weeks following entry, a similar process developed in the right arm at the site of the intravenous aureomycin infusion (Fig. 33E) and over the right deltoid muscle at the site of the penicillin injection. These areas progressed (Fig. 33F) in spite of wide surgical excision and local chemotherapy consisting of streptomycin and sulfomylon until the entire right upper extremity from the deltoid to the wrist was denuded of skin and fascia (Fig. 33G).

Six weeks following entry, while the right and left arms were progressing as described, massive bilateral deep phlebitis of the lower extremities developed with resultant edema from the knees to the toes. No definitive treatment was instituted for the phlebitis. Anticoagulants were contraindicated because of the extensive ulcerating area, and a surgical attack in the groins could not be done for fear of spread of infection to this area. During the ensuing months of hospital stay the edema gradually subsided and no pulmonary emboli were noted.

Finally, after numerous excisions and ultimate skin grafting, the disease appeared to be checked about five months following entry and the extremities were covered with skin. However, while convalescing from these infections, a patch of redness was noted in the left groin which progressed to a similar type of infection in this area that ultimately spread to the right groin (Fig. 33H). While surgery was contemplated, the completely cachectic patient suddenly died.

This case raises many issues. Correct debridement and care of the initial injury should have prevented this infection in the first place. Secondly, the absence of microaerophilic streptococcus on repeated examination of cultures by two bacterologic labora-

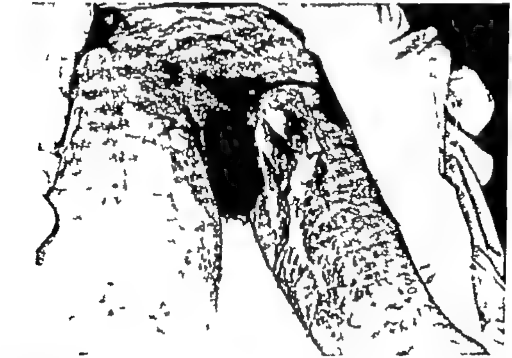

Figure 33G (Top) Further spread of infection to entire right upper extremity

Figure 33H (Bottom) Infection in both groins five months after initial injury

tures there were numerous brachial blocks performed without subsequent local infection It may be that greater care was taken to sterilize the skin before the brachial blocks than before the routine venipunctures and injections The phlebitis in the right arm and both legs with its attendant edema may have produced an area of decreased tissue resistance since it is well known that such edematous areas are more liable to infection than normal areas

The *human bite* produces a symbiotic infection in which the anaerobic streptococci are the most significant organisms These lesions also contain pathogenic actinomycetes fusiform bacilli and spirochetes The initial injury may be a simple abrasion over the proximal phalanges and knuckles or a complete laceration of skin with or without a laceration of the extensor tendon and capsule of the metacarpophalangeal joint Soon there develops a dull aching pain with swelling in the involved area and when seen late a thin cloudy fluid extrudes from the wound (Fig 34) There will be edema and other signs of infection depending upon the anatomical spaces involved The most serious infections are those which involve the metacarpophalangeal joint The surgical anatomy of these infections have been clearly studied [10] The most serious lesions are those over the knuckles and the usual spread of infection is along the dorsal subcutaneous and subaponeurotic spaces If the joint is involved it becomes infected If infection spreads to the adjacent web spaces of the finger it may follow the lumbrical canals to the fascial spaces of the palm The severity of these infections before modern therapy may be evidenced by Boyce s [11] report where out of ninety collected cases there were twenty-one complete amputations of digits three partial amputations and three ostectomies In addition an amputation of an arm had to be performed with one death due to pneumonia

These infections are so serious that one should always be suspicious of any laceration over the metacarpophalangeal joint Often a patient is ashamed to tell that he was involved in a fist fight therefore the true nature of the lesion may not be explained to the examining surgeon

Early treatment consists of soap and water cleansing of the wound for twenty minutes irrigation with sterile saline solution

tories is of interest. Staph aureus was the predominant organism which was occasionally mixed with the various bacteria such as Bacillus pyocyaneus B proteus and enterococci This is similar to the experience of Wilson[8] Thirdly the reason for the spread of this infection to the opposite arm and both groins is not clear Although the involved sites were all areas of previous skin punc

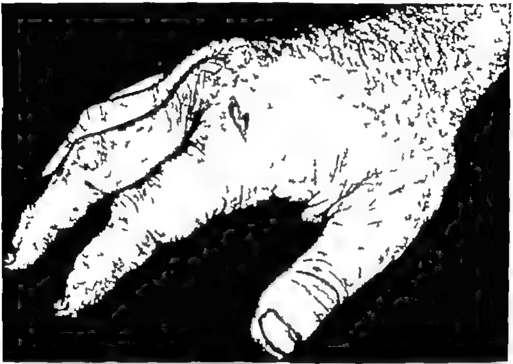

Figure 54 (Top) Human bite infection metacarpophalangeal joint, right index finger with edema and erythema of dorsum of hand and fingers.

Figure 55 (Bottom) Self sustained human bite infection with loss of distal phalanx of fifth finger

Figure 36 (Top) Tuberculous tenosynovitis of ulnar bursa with extention into middle finger (Courtesy Dr John Crandon)

Figure 37 (Bottom) Tuberculous tenosynovitis of left wrist showing infected tissue being dissected from underlying tendons.

leaving the wound open to heal by secondary intention applying a sterile dressing splinting the hand in a position of function and instituting antibiotic therapy Although most surgeons use penicillin as the antibiotic agent, Levin and Longacre [illegible] obtained excellent results with bacitracin in conjunction with other general methods of treatment. The value of this treatment (emphasized by Mason and Koch [10]) was clearly established in the results of a series where fifty five out of sixty-one cases remained clean with only one case of gross infection following early treatment.[13]

When the infection is obvious a surgical incision is necessary Usually this consists of a longitudinal dorsal incision carried not only through the subcutaneous tissues but also into the subaponeurotic space If the metacarpophalangeal joint is involved the joint should be opened by means of two lateral incisions, irrigated, and left open When the infection has spread to a web space or palmar space these are suitably drained The value of antibiotic therapy has been proven in all recent series of human bite infections Using chemotherapy in a second series of human bite cases studied at the Charity Hospital Boyce [14] found that in only three was it necessary to perform a mutilating operation It is of interest that in spite of all that is known about human bite infections they are still sutured and primary suture in seventeen out of seventy of these infections has been reported.[15] Of course in all cases the suturing increased the frequency of severe complications

Rarely is bone involved in human bite infections. Andreasen [16] reports the case of a soldier who received a bite in battle and eventually developed a bone abscess at the head of the second metacarpal bone with no joint involvement

A rarer type of human bite infection may develop when a hangnail is bitten or when through habit a person constantly chews his fingers. We have had an interesting example of this when a young boy with an ulnar nerve palsy was very much impressed with the numbness of his fifth finger and kept biting the tip to see if sensation would return He developed a severe human bite infection and eventually lost a portion of the distal phalanx (Fig 35)

who work with tuberculous patients are frequently liable to this chronic ulcerating lesion

Tuberculous dactylitis is most commonly seen in children and affects the proximal phalanges metacarpals and middle phalanges The distal phalanges are never involved The clinical picture demonstrates a fusiform painless swelling of the involved bone[21-23] The overlying skin may be shiny and red and fistulas may develop If the metacarpals are involved the swelling appears mainly on the dorsal surface of the hand The x ray picture varies from minimal medullary changes and periosteal swelling to a fusiform dilatation of the cortex and widespread destruction of all layers of bone There is a general consensus of opinion that in children conservative therapy consisting of immobilization of the digits and incision and drainage for secondary infection will yield good results When the disease occurs in older children or adults excision or amputation may be necessary particularly if the disease threatens adjacent joints[26] However the advent of chemotherapy may lead one to treat all these cases conservatively and prolonged treatment is recommended consisting of streptomycin and either isoniazid or para aminosalicylic acid for at least ninety days after sinus closure with an additional period equal to one half the time required for sinus closure[27]

Jungling s disease or *multiple cystic tuberculosis* of the bone similarly demonstrates a gradual onset of swelling in a small bone of the hand which may be moderately painful X rays shows a cystic trabeculated expansion of the bone Pathologically there is semi solid granulation tissue characterized by the presence of epithelioid cells arranged in tubercle formation and surrounded by lymphocytes with giant cells Actual necrosis is not seen and the tuberculosis bacillus is not found Skin tests for tuberculosis are negative According to the experience of most observers this disease takes a slow course tending to spontaneous improvement and recovery[29,31] It appears probable that this disease is Beck s sarcoid and not tuberculosis The usual changes of sarcoid are seen in the small bones of the hands and feet. Punched out cyst like lesions occur particularly in the phalanges and occasionally in the metacarpals which may coalesce producing extensive bone destruction The distal phalanges often show the most severe

MYCOBACTERIUM TUBERCULOSIS

This organism may infect tendon sheaths skin bones and joints *Tenosynovitis* is of special interest and has been the subject of numerous reports[17 21] The disease is produced by direct extension of an infection in the hand in people who work with cattle (milkers skinners butchers) or it may be secondary to pulmonary tuberculosis Trauma may be a predisposing factor The third and fourth decades are the most common age groups involved and the sex ratio is approximately three males to two females The pathology of this disease is the same as other types of tuberculosis It affects the synovia first and later involves the tendon and surrounding structures Any tendon of the body may be involved, but usually it affects the exensor or flexor tendons of the wrist, with the volar tendons involved twice as often as the dorsal and the right upper extremity afflicted more than the left.

There is a slow onset of relatively painless swelling (Fig 36) over the involved tendon or tendons with eventual limitation of function At first the swelling is doughy in consistency but as the disease progresses it may become fluctuant When it involves the ulnar bursa it presents an hour-glasss deformity with a confluent mass in the palm and forearm (compound ganglion) The semi fluid mass may be pressed back and forth under the volar carpal ligament If rice bodies are present crepitus may be felt. Usually there are no constitutional signs or symptoms unless the tuberculosis involves other parts of the body Diagnosis is made on the history and physical findings which should be corroborated by culture or guinea pig innoculation of the tissue at time of surgery and by pathologic examination Biopsy of the epitrochlear node of the involved hand may be a helpful diagnostic method[22,23]

A trial of antibiotic therapy with streptomycin and para aminosalicylic acid or isoniazid should be attempted If this fails surgery will be necessary and consists of complete excision of the involved parts (Fig 37) plus immobilization in a plaster cast in a position of function Treatment with streptomycin and para aminosalicylic acid is instituted for approximately six weeks

Occasionally a tuberculous infection of the skin of the fingers will occur from an infected abrasion or cut Doctors and nurses

diseased animals If the source of entry is the skin of the hand a papule like lesion develops which later ulcerates A red granuloma occurs with a surrounding zone of cellulitis Subsequently the center becomes necrotic leaving a punched out ulcer Bacteria spread along the lymphatics with resultant lymphangitis and lymphadenitis In half the cases the glands suppurate Septicemia may develop with foci of infection in the spleen liver lungs lymph nodes bone marrow or other tissues Identification is made by bacterial smear direct culture inoculation in guinea pigs and the Foshay intradermal test Positive blood cultures may be obtained during the first week and agglutinins are demonstrable after ten days Streptomycin is effective in eradicating this disease There is some evidence that aureomycin and chloramphenicol are effective

PASTEURELLA MULTOCIDA

Although this organism is widespread in the animal kingdom producing a hemorrhagic septicemia human infection has been thought to be rare Recently there has been evidence that a localized form of this infection secondary to cat bites is more common than realized[24] Soon after the bite the area becomes painful red and swollen with an ascending lymphangitis and lymphadenopathy An abscess may develop and osteomyelitis frequently occurs (Fig 39) When cultures are sent to the bacteriology laboratory special note should be made of the possibility of such infection since these organisms may be interpreted as other Gram negative bacteria.

All cat bites should receive a thorough soap and water scrub irrigation sterile dressing and tetanus anti toxin or toxoid injections Procaine penicillin (600 000 units) is administered daily for four days.

Once infection has developed hospital admission with roentgenograms of the area and wound culture is advised Penicillin is the antibiotic of choice

BACILLUS ANTHRACIS

This aerobic spore forming organism causes disease in sheep cattle horses and swine Human infection develops from handling

changes (Fig 38) In addition there may be a lattice work of diffuse bone destruction

Fig 38

Fig 39

Figure 38. Sarcoid of fingers demonstrating severe destructive changes in distal phalanges.

Figure 39. X ray of left wrist 14 days after a cat bite, demonstrating osteomyelitis of greater multangular and base of first metacarpal bones caused by Pasteurella multocida.

TREPONEMA PALLIDUM

This organism rarely involves the hand but chancres may occur at the site of a hangnail and be mistaken for paronychia. Tertiary lues may affect the tendon sheaths and bones and joints of the fingers and wrist.

The danger of transmitting syphilis through human bites is emphasized by Sieff [22] who cited four cases. Humphreys [23] stressed the danger to dentists treating such people

PASTEURELLA TULARENSIS

This organism produces infectious disease in rodents and in other wild and domesticated animals such as game birds and domestic chickens Man becomes infected when bitten by an insect vector (tick or deer fly) or when he comes in contact with

duces infection in man by penetrating the skin of the hand through a wound or abrasion and is most commonly observed in abattoir workers and fish handlers[37] It also is seen in the whaling and sealing industry and is known as whale seal or blubber finger[38,39] Although diagnosis is made by biopsy and culture it should be suspected on clinical grounds Within a day or two after initial injury there develops an erythematous swelling with a somewhat taut and shiny appearance accompanied by itching and stiffness of the part (erysipeloid) Lymphangitis and lymphadenitis may occur Rarely septicemia with endocarditis has been reported[37]

Treatment is conservative and surgical incision should not be performed since suppuration does not occur However the disease may be mistaken for tenosynovitis and flexor tendon sheaths have been opened by mistake[40] Penicillin is the antibiotic of choice and should be continued after cessation of symptoms to prevent recurrences[41 42]

ACTINOMYCETES BOVIS

Frequently cattle swine or horse workers are invaded by *actinomycetes bovis* through an abrasion or wound of the hand There is a granuloma similar to that of tuberculosis which will remain for months as an indolent nodule with occasional sinus formation It may cover the entire dorsum of the hand Diagnosis is made by microscopic examination and culture of the draining material. Penicillin together with large doses of potassium iodide may be of benefit in treatment[43] Isoniazid (Nydrazid) has been reported as beneficial[44]

Mycetoma or Madura foot has been known for years but recently there is evidence that a similar condition can appear in the hand Myerding and Evert[45] report a case of a thirty nine year old Mexican who was first seen with swelling of the palm of the hand which had been present for seventeen years He had several operations and two courses of x ray therapy but induration persisted over the base of the left first metacarpal bone from which there were several draining sinuses containing black granules which proved to be colonies of Madurella. He had subsequent x ray and potassium iodide therapy and excision but

such animals on the farm or from manufacturing and processing their products in factories and canneries. A red macule develops that enlarges and produces a vesicle which ruptures leaving a characteristic black gangrenous base There may be surrounding vesicles The lymph glands will become enlarged and tender with associated malaise and fever The disease may produce septicemia with subsequent pneumonia endocarditis and meningitis There is evidence that a specific edema producing lethal factor is present in the plasma of animals dying of anthrax and thus may play a role in the mortality resulting from this disease A study of this lethal factor leads to the belief that the protective antigen of B anthracis is a toxoid form of this specific lethal factor [38] Penicillin therapy appears to be very effective.[39]

MALLEOMYCES MALLEI

This organism produces a rare disease in which the infected mucus from horses mules or donkeys enters an abrasion of the hand causing an initial lesion that is called farcy A granulomatous lesion develops which ulcerates and becomes encircled by small vesicles and pustules with associated lymphangitis and lymphadenitis The ulceration may spread into the muscles or infection may spread to the lungs peritoneum skin joints and bones Diagnosis is made by smear culture and guinea pig inoculation There is also a subcutaneous mallein test agglutination test and a complement fixation test

NEISSERIA GONORRHOEAE

This produces tenosynovitis of various tendon sheaths or arthritis of the wrist and finger joints The acute tenosynovitis may be difficult to diagnose from an ordinary pyogenic infection Diagnosis is made by smear and culture of the infected tissue Penicillin is the antibiotic of choice

ERYSIPELOTHRIX RHUSIOPATHIAE

This organism is found in a wide range of animals and produces swine erysipelas It survives in decomposing nitrogenous material and often is found *in decomposing fish shellfish or meat It pro-*

COCCIDIODES IMMITUS

This organism rarely affects the hands When it does it produces skin nodules or ulcers Diagnosis is made by examination of smear culture and complement fixation tests Goren[48] reports a case of osteomyelitis of the middle phalanx of the left index finger due to a cut with a jagged tin can Following amputation of the finger the gross specimen showed osteomyelitis composed of tubercles made up of epithelioid cells and giant cells in the center of which there was necrosis and caseation Within this material were seen spherical bodies with double-contoured refractive membranes and *coccidioides* were found in the tissues A coccidioidin skin test and complement fixation test were positive

Walker and Hall[49] report an interesting case of tenosynovitis of the ulnar and radial bursa in a patient who on pathological examination showed doubly refractile spherules with endospores and a diagnosis of coccidioidomycosis was made Serum complement fixation and coccidioidal skin tests were positive This is the first reported synovial manifestation of coccidioidal infection

MYCOBACTERIUM ULCERANS

An interesting case of this disease was that of a Mexican farmer who developed an infecton in the terminal portion of the index finger which in spite of treatment progressed to involve the entire finger requiring surgical obliteration[50] Tuberculin and lepromin tests were positive Histologic examination of the tissues showed acid fast bacilli After two months there developed a growth of an acid fast bacillus which had the cultural characteristics of *M ulcerans* Treatment consisted of DDS and antibiotics to control the secondary infection This subsequently healed at the end of eight months

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there was recurrence of the disease eighteen months later

Moore [46] had a somewhat similar case in a patient with a swollen right arm who never left Mississippi or Missouri There was a small (2.5 cm) non tender freely movable nodule in the skin over the outer surface of the right wrist which had been present for approximately fifteen years Eventually the area became larger and at the time of observation the right hand and forearm were swollen and discolored up to the elbow demonstrating numerous soft fluctuant unruptured and ruptured nodules There were many draining sinuses from which could be obtained a thick sticky blood streaked exudate or discharge There were noticeable changes in the carpal bones with almost complete resorption of the greater multangular and trapezium Cultures of the exudate showed the organism to be a species of *Madurella*. He was treated with penicillin terramycin potassium and sodium iodide but after demonstrating no response the arm was amputated Microscopic section showed marked fibrosis and chronic inflammation around large masses of the organism In addition there were many inflammatory cells such as polymorphonuclears eosinophils and small round cells with many large foam cells and mononuclears.

BLASTOMYCES DERMATITIDIS

Infection of an abrasion or wound of the hand by this organism produces a papulopustule which spreads peripherally The center may heal leaving a scar surrounded by a spreading border A systemic type of disease beginning in the lungs with a hematogenous spread to the skin and bones may occur Diagnosis is made by smear and culture of the draining material Iodides and x ray have been advised for treatment.

SPOROTRICHUM SCHENKII

This widely distributed fungus may infect the extremities through abrasions of thorn pricks A pustule or abscess develops with invasion of regional lymphatics producing a thickening of the lymph vessels with multiple granulomas along the course of these vessels which may rupture spontaneously Diagnosis is made by examination and culture of the draining material Treatment with iodides may be of value [47]

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CHAPTER 5

ANATOMICAL LOCALIZATION

When suppuration develops in the hand it localizes in various anatomical spaces which must be incised adequately in order to drain the purulent material Such incisions should avoid tactile surfaces of the fingers and palms and should not cross flexion creases. An exact knowledge of the various spaces is essential to prevent damage to underlying and adjacent structures

PULP SPACES

Infection in the distal pulp space of the finger one of the most commonly involved areas in the hand is more commonly known as a *felon* The distal pulp space is separated from the pulp space of the more proximal phalanx by an oblique septum which passes from the skin of the interphalangeal crease to the fibrous tendon sheath[1] The fascia extending from the skin to the periosteum of the distal phalanx divides the pulp space into many fat containing pockets The most common infecting organism is Staphlococcus aureus which enters the space through puncture wounds

The fingertip becomes painful swollen indurated and tender (Fig 40) Since the appearance of suppuration indicates immediate incision many authors have attempted to correlate this with clinical signs Harrison *et al*[2] found that when the finger was swollen more than 12 per cent it would almost invariably contain pus Murray[3] grades the tension in the finger as follows Grade I a slight resistance to the examining finger Grade II a firm rubbery resistance Grade III a hard and woody sensation In Grade I cases necrosis was present in 27 per cent Grade II 40 per cent Grade III 55 per cent. He therefore believes that tension in the finger indicates the amount of underlying tissue necrosis He also finds that the intensity of pain is in direct proportion to

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Treatment is instituted as soon as there is evidence that pus has accumulated The earlier the treatment the quicker the healing time and the fewer the complications [2,6,12,14]

Although there is much dispute concerning the matter the author believes the correct incision should begin on one side of the proximal third of the distal phalanx be carried around the end of a finger passing just beneath the nail to the opposite corner of the nail and extend for another half centimeter on the opposite side of the phalanx (Fig 41a) The fibrous septa connecting the periosteum to the skin are cut through making the entire pulp space one cavity (Fig 41b) In this manner the distal pulp will be opened as a flap and will not close due to edema All necrotic and sloughing tissue is excised (Fig 41c) [15,17] If loose bone is found in the pulp it is removed There are many cases of complications arising from such incisions but these are caused by carrying the incision across the tactile surface of

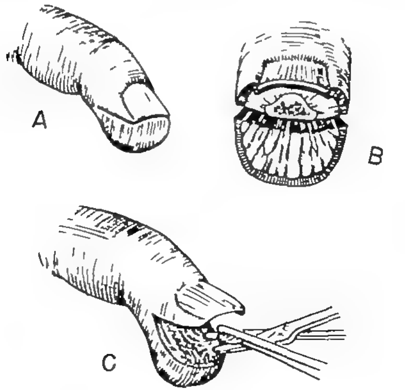

Figure 41 Surgical treatment of a felon. A) Incision around tip of finger just beneath nail B) All fibrous septa are incised. C) Necrotic tissue is excised.

the degree of tension and the old observation that "if the patient has had a sleepless night owing to pain operate was based on sound observation Several authors have advised transillumination of the infected pulp space to precisely localize the appearance of pus.[4,5]

Figure 40 Felon of right thumb.

If felons are not adequately drained at an early stage, they will develop complications such as skin and fascia necrosis and osteitis. The complication rate varies as follows Harrison *et al.*, 47 per cent [2] Bailey 21 4 per cent [6] Pilcher *et al* 24 per cent,[7] Robins, 60 per cent.[8] The presence of these complications will triple or quadruple the healing time of the infected finger

The age of the patient bears some relation to the presence of complications Barclay [9] found that only 10 per cent of patients with osteitis of the terminal phalanx were under the age of thirty whereas 60 per cent of the uncomplicated cases were in this age group

The osteitis may be produced by ischemia of the diaphysis of the terminal phalanx caused by the increasing pressure of the infection [1] Bolton *et al* [11] challenge this concept of occlusion of the digital vessels and believe that bone involvement is due to direct extension of infection to the periosteum However it is possible that both mechanisms play a role.

similar group of observers always place their incision at the site of sinus formation.[2,6,8,10,20] A bolder approach has been an incision of the felon with excision of necrotic tissue and immediate suture.[2,12,20,21] However, a review of the most recent of these articles revealed that when there was primary healing the average time was eleven days.[21] When there was no primary healing, the average healing time was thirty four days. In other words, when primary healing takes place by this immediate suture, the average healing time is about the same as for the standard drainage methods. If it does not occur, the healing time is prolonged. The success of these various modifications of the limited incision method seems to rely on penicillin.

Harrison *et al*[8] found that 90 per cent of infections were caused

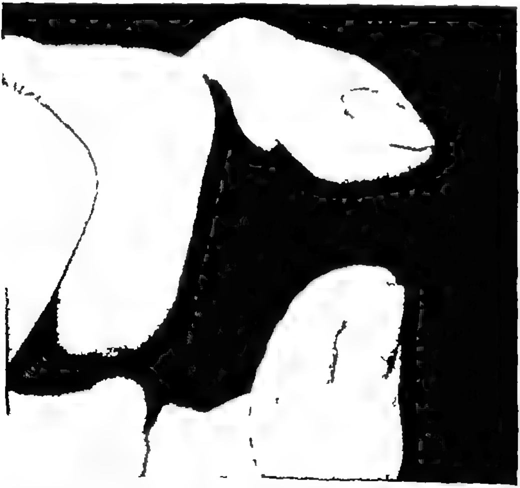

Figure 45. Properly placed incisions for felons of thumb and index finger give excellent results.

the thumb thus giving rise to skin necrosis dorsal to the incision and to a scar on the tactile area (Fig 42)[10-19]

A deviation from this incision is made only in cases where a sinus has developed with necrosis of adjacent skin An elliptical incision around the sinus including the necrotic skin to establish drainage will be satisfactory Since the sinus already is present it is not possible to prevent a scar on the tactile area

Figure 42. Poorly placed incision for felon producing deformed fingertip.

Following incision and drainage as previously described a rubber drain is placed in the wound for forty-eight hours after which daily soaks are instituted and a dry sterile dressing applied between soaks. This method of treatment gives a good functioning fingertip without a scar on the sensitive area (Fig 43)

Since the advent of penicillin there have been many variations in the types of treatment advocated most from Great Britain Numerous authors advised placing an elliptical incision at the site of pus accumulation and fashioning the incision so that the pus cavity is saucerized. No drains are inserted The incision usually is placed in the direction of Langer's lines[2,6,7,12,16,19] A

the eponychium and paronychium which often follow infection at the base of hangnails Pus may be limited to one small area in the paronychium or eventually spread completely around the base of the fingernail and underneath the nail stripping it from its bed In a series of 572 cases the fingers were found to be involved as follows thumb 167 index 111 middle 157 ring 105 and fifth 31 [4]

In an early paronychia drainage may be accomplished by merely pushing away the paronychium and allowing a drop of pus to exude the more complicated cases require the classical incision of Kanavel (Fig 44) Two incisions are made at the

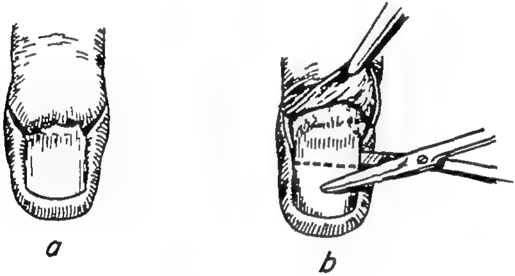

Figure 44 Surgical treatment of paronychia a. dorsilateral incisions distal to nail matrix b excision of proximal half of nail if pus is beneath it.

lateral angles of the nailbed distal to the lunula so as to avoid damaging the nail matrix They are extended lateroproximally and the eponychial flap lifted from the nail If pus is found under the nail it is essential that the entire width of the proximal nail be removed since if a portion is left granulation tissue may push through the defect and become persistent.

The complications of paronychia have been reported by numerous authors Bailey [6] found 11 9 per cent complications *in over* 500 cases The most common were stiffness of the interphalangeal joint and prolonged sloughing of tissue Other complications in

by strains of staphylococcus aureus which were penicillin sensitive When penicillin resistant organisms increase in Great Britain they probably will resort to more adequate incision and drainage

Some surgeons still rely on x ray for treatment of felons [22,23]

There is a variant of abscesses of the distal pulp space known as the *apical abscess* [6,7] This lies in the distal pulp space under the nail bed and anterior to the phalanx Osteitis seldom occurs and hence the average healing time is short. Treatment consists of incision and drainage of the anterior distal pulp space by an incision just underneath the nail bed The lateral prolongations on either side of the finger are not necessary

Another infection of the finger that may simulate a felon when it occurs along the distal pulp is a *sub-epithelial abscess* in which the underlying pus can be seen through the thin epidermal wall *It merely requires an unroofing without anesthesia* However it must be cautioned that this occasionally may mask an under lying deep abscess in which a sinus tract can be demonstrated leading to the subepithelial abscess

The pulp spaces of the middle and proximal phalanges may suppurate and usually are referred to as *subcutaneous abscesses* of the fingers. They are commonly caused by staphylococcus and require incision and drainage by a mid lateral incision along the involved phalanx using the lateral edges of the digital crease as a landmark for the incision They are not complicated by bone infection as are ordinary felons but the following complications have been found delayed separation of slough residual stiffness of the finger involvement of tendon sheath and interphalangeal joint [8] Another obvious complication may be the development of a web space abscess when infection travels along the lumbrical canal from the proximal phalanx into the web space. When the subcutaneous infection or felon of the proximal phalanx is opened by a lateral incision care should be taken to avoid interference with the web space The incision is placed along side of the phalanx and carried over the dorsal surface of the web space so as not to damage the web fold [15]

PARONYCHIA

Paronychias are subcuticular and intracutaneous infections of

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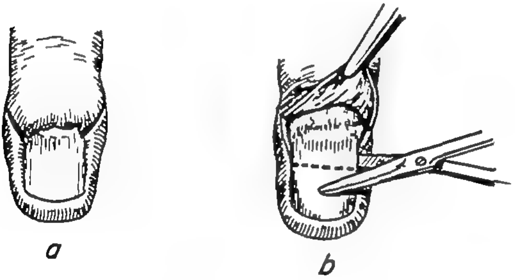

Figure 44 Surgical treatment of paronychia. a. dorsilateral incisions distal to nail matrix. b excision of proximal half of nail if pus is beneath it

lateral angles of the nailbed distal to the lunula so as to avoid damaging the nail matrix. They are extended lateroproximally and the eponychial flap lifted from the nail If pus is found under the nail it is essential that the entire width of the proximal nail be removed since if a portion is left granulation tissue may push through the defect and become persistent

The complications of paronychia have been reported by numerous authors Bailey [6] found 11 9 per cent complications in over 500 cases The most common were stiffness of the interphalangeal joint and prolonged sloughing of tissue Other complications in

clude lymphangitis and extension of cellulitis from the distal phalanx up the finger Rarely the infection may extend to the pulp space and very rarely is bone involved Most of the complications are secondary to inadequate primary operation [7,14]

Lowden [14] found two cases of gangrene of the finger and three in the toe provoked by operations for paronychia He points out that circulatory inadequacy should be carefully investigated in all cases to avoid such complications He also lists suppurative arthritis as another complication of paronychia and believes that joints afflicted with chronic arthritis are particularly susceptible to secondary infection

Chronic paronychia should make one suspicious of fungus infection which is quite common in people whose hands are frequently immersed in water Treatment of this consists of keeping hands dry and using rubber gloves whenever possible as well as substituting a soapless detergent for cleansing purposes The infected areas can be treated with one per cent aqueous solution of Gentian violet, or ammoniated mercury (5 per cent) ointment applied twice daily

WEB SPACES

The web spaces between the fingers are compartments bounded on either side by slips of palmar fascia extending from the pretendinous bands down to the proximal phalanges Proximally the web spaces are outlined by the superficial transverse palmar ligament distally by the natatory or intradigital ligament Volarly there is a fat pad overlain by the volar skin and dorsally the dorsal skin of the web space This space contains the digital nerves and arteries and the lumbrical muscle on the radial side of the finger

The tissue in this space is a common site of infection from skin abrasions calluses or splinters The infection usually will point on the palmar aspect of the web space but may spread dorsally by lymphatic invasion or direct spread It also may extend along the lumbrical canal either distally into the proximal phalanx or proximally into one of the palmar spaces Treatment of an abscess in this space requires a curving incision over the volar

surface of the interspace (Fig 45A) A dorsal extension of the infection may be reached by a longitudinal incision on the dorsum of the web (Fig 46A) The web should not be incised completely since this will lead to an adduction contracture of the fingers Several authors advise a transverse incision over the web space with excision of some adjacent skin and subcutaneous tissue so as to promote drainage[6,7] Kole[17] uses a longitudinal spindle shaped incision similarly excising some of the adjacent skin

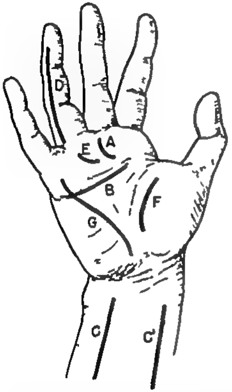

Fig 45

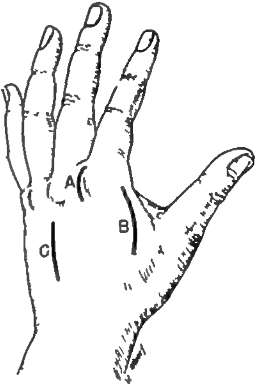

Fig 46

Figure 45 Incisions for draining infections of the hand. A web space B mid palmar C and C' quadrilateral space of the forearm D and E, digital tenosynovitis F radial bursa G ulnar bursa.

Figure 46. Incisions for hand infection. A, web space B, thenar space C, dorsal space

Occasionally people dealing with hair or hides may develop lesions produced by short hairs which work into the skin and stimulate a foreign body reaction In the dairy industry these are known as milker's granuloma Matheson[28] reports this

type of sinus in the web space of a wool worker There have been *numerous cases reported that have been found in barbers.*[26-28] These resemble *pilonidal sinuses* and are caused by the hairs becoming embedded in the skin giving rise to an infection which produces a small opening [26] As a result of repeated entries of hair the opening persists and becomes larger with eventual epithelialization of the cavity Ten lesions have been found among seventy seven gentlemen hairdressers but none among sixty-one lady hairdressers demonstrating that it appears to be due to short hairs rather than long Joseph *et al* [29] found the disease in fifteen of 115 barbers These authors studied thirty specimens taken from the interdigital webs but could find no hair follicles demonstrating that the hairs in the sinuses were extraneous and penetrated the epidermis directly and not through a hair follicle

SUPERFICIAL PALMAR FAT PADS

In the palm of the hand there are fat pads over the thenar and hypothenar eminences which may be the site of an abscess These pads may be confused with some of the more important palmar spaces Treatment consists of incision over the area of fluctuation

THENAR AND HYPOTHENAR MUSCLE SPACES

The fascia covering the hypothenar and thenar muscle groups form potential spaces which may be the site of abscesses. These are drained by suitable incisions over the area of maximum tenderness and fluctuation Care must be taken to drain the thenar *muscle space abscess at some point distant from the motor* branch of the median nerve This point has been well described by Kaplan [30] using the cardinal line as a landmark This line is drawn from the apex of the interdigital fold between the thumb and index finger parallel with the middle crease of the palm of the hand passing near the distal pole of the pisiform bone The intersection of this line with the thenar crease corresponds to the underlying motor branch of the median nerve

PRETENDINOUS PALMAR SPACE

This space which has been described by Iselin [31] and Birks [32]

is the space between the palmar fascia and the underlying flexor tendons lumbrical muscles and ulnar bursa (Fig 47)

Infection in this space usually follows direct injury to the palm and is manifested by swelling with all the fingers held in semi flexion It may be difficult to distinguish this space from a mid palmar abscess It should be drained early so that the palmar fascia does not become involved delaying healing due to sloughing of fascia The incision should be made transversely over the involved area going through the skin and fascia

MID-PALMAR SPACE

This space lies between the tendons of the fifth fourth and third fingers and the interosseous fascia (Fig 47) The medial

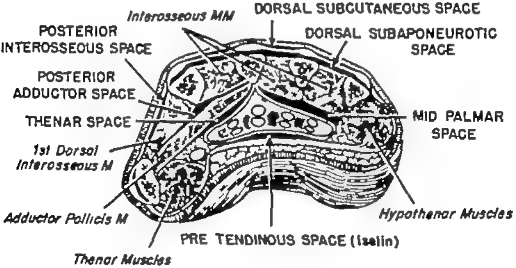

Figure 47 Diagrammatic cross section of hand demonstrating important fascial spaces.

wall is formed by the septum extending from the palmar aponeurosis to the fifth metacarpal bone which separates the opponens muscle from the fourth volar interosseous muscle. The dorsal wall is the volar interosseous fascia covering the interosseous muscles in the third and fourth intermetacarpal spaces and the fourth metacarpal bone The volar boundary is the ulnar bursa surrounding the tendons of the fifth fourth and third fingers The lateral boundary has been much disputed Flynn [33] found

it present in 100 dissected hands and believes it to be fascia from the undersurface of the flexor tendons of the middle finger extending along the entire length of the middle metacarpal bone Kaplan [30] believes *it is the attachment of the ulnar bursa to the* fascia over the third metacarpal bone and in the hands dissected by the author this would seem to be the most logical explanation Jamieson [34] describes it as the oblique septum which is roughly a quadrilateral septum distinct from the aponeurotic septa of the palmar fascia extending from the volar surface of the third meta carpal bone in common with the origin of the adductor transversus pollicis which passes obliquely in the same direction as the fibers of the adductor transversus pollicis to join the undersurface of the palmar aponeurosis and splitting to enclose the tendons to the index finger and the first lumbrical muscle Although there is a difference of opinion as to the origin of this septum there is certainly confirmation of Kanavel s original demonstration of its presence

Distally the mid palmar space empties into the third and fourth web spaces and along the lumbrical canals of the three medial fingers Proximally the ulnar bursa is so adherent to the posterior carpal tunnel that there is virtually no communication between this space and the quadrilateral space of the forearm

An abscess develops in this space following puncture wounds or web space infections Other causes may be septic abrasions suppurative tenosynovitis osteomyelitis and septic lacerations. The clinical picture is manifested by swelling and tenderness in the central area of the palm The third fourth and fifth fingers may be held in partial flexion and usually there is dorsal edema

Drainage is instituted by a transverse incision over the area of maximum swelling which is carried through the palmar fascia (Figs 48 and 45B) The tendons and nerves are bluntly pushed aside and the pocket of pus underneath is isolated After removal of pus and irrigation of the wound any necrotic sloughing fascia *is excised and a rubber tissue drain inserted to keep the wound* edges open Following incision and drainage the hand is placed in the position of function At the end of forty-eight hours the drain is removed and the hand soaked daily with half strength Dakin s solution

The prevalence of antibiotics has reduced the incidence of this infection so that Flynn[25] found thirty cases over a seven year period in the pre-antibiotic era and only four over a five year period in the antibiotic era.

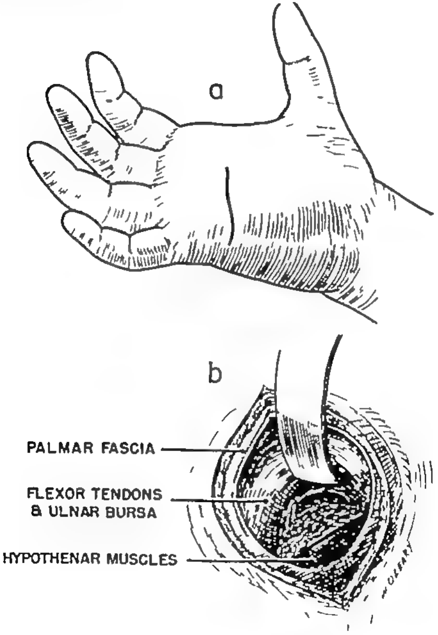

Figure 48. Surgical treatment of mid palmar space abscess.

it present in 100 dissected hands and believes it to be fascia from the undersurface of the flexor tendons of the middle finger extending along the entire length of the middle metacarpal bone. Kaplan [40] believes it is the attachment of the ulnar bursa to the fascia over the third metacarpal bone and in the hands dissected by the author this would seem to be the most logical explanation Jamieson [34] describes it as the oblique septum which is roughly a quadrilateral septum distinct from the aponeurotic septa of the palmar fascia extending from the volar surface of the third meta carpal bone in common with the origin of the adductor transversus pollicis which passes obliquely in the same direction as the fibers of the adductor transversus pollicis to join the undersurface of the palmar aponeurosis and splitting to enclose the tendons to the index finger and the first lumbrical muscle Although there is a difference of opinion as to the origin of this septum there is certainly confirmation of Kanavel s original demonstration of its presence

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on the dorsum of the web space (Fig 49) The index finger may be held in slight flexion and active and passive motion may produce pain In order to distinguish this infection from other abscesses and infections in the area Moses[27] proposed the following test If an object such as a broken kitchen match is placed between the thumb and index finger and the patient attempts to approximate the thumb to the index finger by pressing against the edges of the match a contraction of the adductor pollicis muscle alone will take place If this muscle is overlain with pus contraction of it will cause pain at the base of the thumb whether or not there is any motion in the metacarpal

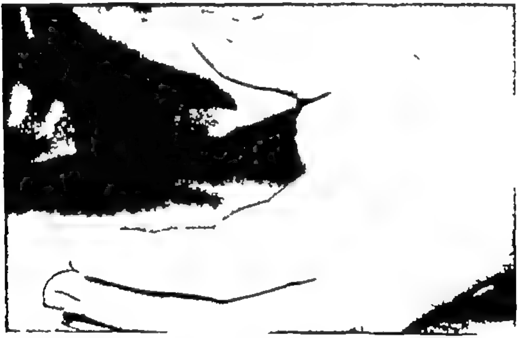

Figure 49 Thenar space abscess of left hand with thumb held in abduction Web space between thumb and index finger markedly swollen and indurated

A posterior adductor space abscess will appear more on the dorsal surface of the first web space and the index finger can be moved without pain

Infection of the thenar space usually occurs from puncture wounds and rarely from suppurative tenosynovitis septic abrasions burns osteomyelitis septic lacerations and extension of lumbrical space infections of the index finger

THENAR SPACE

The thenar space should not be confused with the thenar muscle space or the fat pad over the thenar eminence The thenar space is a wedged shaped space the floor of which is formed by the volar surface of the adductor pollicis muscle. The lateral wall comprises the three muscles of the thenar eminence The medial wall is the medial septum which has been previously described The anterior boundary is the flexor tendons and lumbrical muscles of the index finger medially and the skin over the thenar eminence laterally Distally this space terminates by fusion of the palmar aponeurosis with the fascia of the first dorsal interosseous muscle where it blends with the fascia of the distal edge of the adductor pollicis

Since an abscess in this space has such a close connection with the adductor muscle it often is called the adductor space rather than the thenar space[94] Pus from the anterior surface of the adductor muscle can make its way distally and lie dorsal to the adductor pollicis muscle[10] Lannon[36] believes that in the web space between the thumb and index finger there are three deep fascia spaces (Fig 47) The space anterior to the adductor muscle is the usual thenar space Between the adductor muscle and the first dorsal interosseous there is a potential space which he calls the posterior adductor space being of the opinion that infection from the thenar space cannot make its way to this area There is also a potential space between the first dorsal interosseous muscle and the deep extensor fascia extending from the second to the first metacarpal bone a so-called posterior interosseous space

Thus it appears that around the thumb there are potentially the following spaces the subcutaneous space in which an abscess could develop at any location around the base of the thumb and thenar eminence the muscle bellies of the thenar eminence the thenar space the posterior adductor space and the posterior interosseous space

An abscess in the thenar or adductor space is manifested by swelling and tenderness immediately distal to the thenar eminence in the web space between the thumb and index finger The thumb usually will be held in abduction and there will be induration

hours following which soaks are begun The hand is placed in the position of function and chemotherapy instituted depending upon the organism found and sensitivity tests of this organism

DORSAL SPACES

Clinically there are two dorsal spaces on the hand a *subcutaneous space* between the skin and the extensor tendons with their

Figure 51 (Top) Thenar space abscess six days after adequate drainage.

Figure 52. (Bottom) Tenosynovitis of right index finger demonstrating characteristic position of finger

Drainage of the thenar space is performed by a curved incision on the dorsum of the thumb index web parallel to the anterior surface of the second metacarpal bone (Figs 46B and 50) The incision is carried through the fascia of this space, and the first dorsal interosseous is retracted ulnarly until the border of the adductor pollicis muscle is found A hemostat gradually is inserted anterior to this edge and the abscess cavity entered This

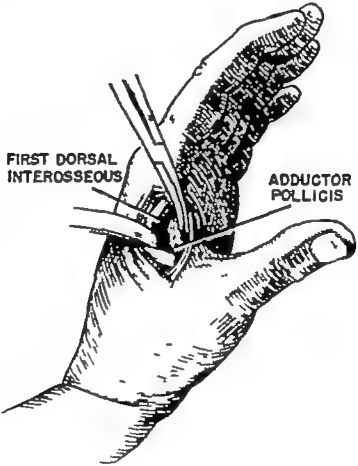

Figure 50. Surgical treatment of thenar space abscess.

incision can be used for infections of the posterior interosseous space and posterior adductor space as well as the usual thenar space. *This eliminates an incision on the volar surface of the palm* and obviates any necessity of endangering the motor branch of the median nerve (Fig 51) After the abscess is opened necrotic fascia is excised and a rubber tissue drain inserted for forty-eight

as before antibiotics The most common organism is either hemolytic streptococcus or Staphylococcus aureus with the remainder being various combinations of organisms [39] Rarely it may be due to gonococcus

The cardinal signs of tenosynovitis have been reported by Kanavel [10] and are tenderness over the involved tendon sheath pain on hyperextending the finger flexion deformity of the involved finger (Fig 52) and swelling of the involved part In order to distinguish tenosynovitis from subcutaneous cellulitis Moses [39] uses the following test

The nail of the involved finger is fixed by the examiner so that actual flexion will not be allowed The patient is then to attempt flexion and if tenosynovitis is present this will cause pain Since however the finger does not move a cellulitis will not produce pain

Gillies [40] points out that these classical signs are seen only when the tendon sheath is intact. Once tension is released either by leakage from a wound or by rupture of the sheath at its proximal end the flexed finger sign may disappear

The author agrees with most American surgeons that tenosynovitis should be incised as early as possible The most useful incision is a mid lateral one extending the entire length of the finger (Figs 45D and 53) The ends of the digital creases serve as land marks for the lateral plane of this incision It also is necessary to make a curved incision over the palmar cul-de sac of the tendon sheath (Figs 45E and 54) After the infection is adequately drained rubber drains are placed to keep the skin open but are not included in the tendon sheath in order to prevent necrosis In forty-eight hours the drains are removed and daily soaks are begun with half strength Dakin s solution and the hand placed in the position of function in between soaks Flynn [36] studied 100 cases wherein the classic incision was performed without chemotherapy and found good results in 33 per cent fair in 20 per cent and poor in 47 per cent When seventy five cases were similarly incised in addition to the use of antibiotics he found good results in 68 per cent fair in 16 per cent and poor in 16 per cent At the same time the complications of the disease—such as amputation

intratendinous fascia and the *subaponeurotic space* between the extensor tendons and the metacarpal bones and interosseous fascia. These spaces are drained by a longitudinal incision taking care to avoid the underlying tendons (Fig 46C) Longitudinal incisions are used to prevent section and ligation of lymphatics which may lead to protracted edema puffiness and stiffness of the fingers.

Carbuncles occur most frequently on the dorsum of the first phalanx of the finger although they may appear anywhere on the hand The principles of treatment of carbuncles in other parts of the body are applicable to the hand In addition to chemotherapy surgery is performed to incise pyogenic cavities and excise necrotic tissue X ray may occasionally localize the infection One must always remember that carbuncles are prone to develop in diabetics.

QUADRILATERAL SPACE OF THE FOREARM (Parona)

This space is bounded dorsally by the pronator quadratus muscle and the interosseous membrane of the forearm volarly by the flexor digitorum profundus tendons radially by the flexor carpi radialis and ulnarly by the flexor carpi ulnaris. Distally it communicates with the carpal canal where it has a relation with the radial and ulnar bursae Infection may spread to the quadrilateral space from tenosynovitis of these bursae Clinically there is swelling and tenderness of the entire volar aspect of the forearm The abscess may be drained by a longitudinal incision parallel with the medial borders of the radius or ulna taking care to avoid the underlying structures (Fig 45C C[1])

TENDON SHEATHS

A knowledge of tendon sheath anatomy is a basic requirement for correct surgical treatment of tenosynovitis The usual anatomical patterns have been discussed in the chapter on anatomy Infection of the tendon sheath is caused by a puncture wound or spread from neighboring processes such as felons of the proximal phalanx human bites burns etc Since the advent of antibiotics the number of tenosynovitis cases is about one fourth as common

tendon sheaths with subsequent irrigation by penicillin (either by needle or in-dwelling catheter) or by small lateral incisions with irrigation by penicillin are all that are necessary.[2,7,9,17,20,40,41,43]

This difference of opinion as to the proper incision between American and European authors is difficult to reconcile. Certainly an infection with an antibiotic sensitive organism could be conservatively treated by a small incision to establish the diagnosis plus the proper antibiotics. But such a sensitivity study may take a day or two and if a wrong guess was made the tendon is lost. Is it not better to use a method proven before antibiotics and to use these as an adjunct rather than a substitute?

When the *radial bursa* is involved, there will be the usual signs of tenosynovitis in the thumb associated with tenderness along the course of the bursa. In addition to the usual digital incision on the thumb, the bursa may be drained by a curved incision over the ulnar aspect of the thenar eminence, taking care to avoid the underlying motor branch of the median nerve (Fig. 45F). The cul-de-sac of the radial bursa in the wrist is found and drained through a longitudinal incision immediately ulnar to the distal three inches of the flexor carpi radialis (Fig. 45C[1]). If the volar carpal ligament must be incised to drain this tendon adequately, it should be opened on its lateral side rather than in the middle to avoid prolapsing of tendons.

Infection in the *ulnar bursa* presents a swelling on the palmar and dorsal surfaces. There is tenderness along the course of the tendon sheath of the fifth finger and along the ulnar bursa. There may be tenderness just proximal to the transverse carpal ligament in the wrist. All the fingers are held semi-flexed and pain is produced on attempting passive extension. There is limitation of motion of the wrist. The incisions to be used in opening this infection are a mid-lateral incision along the fifth finger, a curving palmar incision which just skirts the hypothenar eminence (Fig. 45G) and an incision just radial to the distal three inches of the ulna (Fig. 45C). The fascia of the forearm is incised in line with the forearm incision, and the flexor carpi ulnaris is retracted radially. The pronator quadratus muscle is exposed and lying on its distal portion is the bulging cul-de-sac of the ulnar bursa which is incised. If the bursa has ruptured into the quadrilateral

tendon slough osteomyelitis, thenar and mid palmar space abscesses septic arthritis radial and ulnar bursitis and abscess of the quadrilateral space were markedly decreased

Other authors found that the classical incision is not necessary and that small incisions on the distal and proximal ends of the

Figure 53 (Top) Mid lateral incision for tenosynovitis of finger

Figure 54 (Bottom) Curvilinear incision over proximal cul-de-sac of tendon sheath.

other organisms spread in this fashion Clinically there is a high temperature tachycardia and malaise associated with red streaks along the course of the lymphatic vessels The enlarged lymphatic vessels often may be palpated by oiling or greasing the skin and palpating over this Treatment consists of penicillin plus immobilization with warm moist packs.

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space of the forearm a counter incision is made on the opposite side of the forearm.

JOINT SPACES

The joints may become infected by trauma spread from neighboring infections or metastasis The most common organisms are streptococcus staphylococcus and rarely gonococcus.

Infection in the digital and metacarpophalangeal joints may present swelling redness tenderness excessive mobility and crepitus X ray will reveal the disease by the second or third week when decalcification and erosion of the joint line may be seen When the infection spreads beyond the joint it tends to spread dorsolaterally since the capsule is most thin at this point. Rarely the infection may spread anteriorly into the flexor sheaths particularly at the proximal interphalangeal joint. Treatment is by chemotherapy surgical incision and immobilization in the position of function Usually two lateral incisions over each joint are sufficient for adequate drainage Motion is started as soon as the infection has subsided

Infection of the wrist joint is demonstrated by swelling pain and tenderness in the region of the wrist A persistent swelling on the dorsum of the wrist is fairly pathognomonic Crepitus in this joint is a late manifestation X ray taken during the second or third week of the disease will show disintegration of the carpal bones The principles of treatment are the same with the wrist joint as in other joints The incision usually is performed over the ulnar side of the wrist as recommended by Bunnell [46] Through a lateral incision over the joint the tendon of the flexor carpi ulnaris is severed at its insertion The wrist joint can be opened widely by cutting the joint capsule and necrotic carpal bones removed if necessary The head of the ulna is removed to permit pronation and supination Immobilization should include the upper arm to prevent supination and pronation The position of the wrist should be midway between supination and pronation with about fifteen degrees dorsiflexion

LYMPHATICS

Lymphangitis usually is produced by streptococci but many

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PART III
TRAUMA

CHAPTER 6

GENERAL PRINCIPLES

Hand injuries are responsible for enormous economic and social losses to a nation Koch [1] and Flynn [2] report that one third of the 2 000 000 occupational accidents that occur each year involve the hands and forearm producing a tremendous financial burden In one plant alone Barden [3] reports that 47 per cent of 7 356 accidents resulted in injuries to the hands and wrist These figures staggering as they are do not take into account the anxiety pain and psychological damage to the injured person When one realizes that the great majority are due to the human element these injuries are all the more tragic. Barden [3] found that 85 per cent of cases are due to difficulties ranging from pure carelessness to horseplay fatigue family troubles illness supervisory incapability and plain mental incapacities Poor job selection was an after math of the last war when men who were not properly qualified took on a job developed seniority and could not be transferred Only 15 per cent of his cases were due to failure of machines poor design of operation poor lighting of operation etc

All severe lacerations of the hand require care in the operating room An adequate history should be taken and physical examination performed to discover systemic disease The history is of great importance in ascertaining factors essential to therapy such as the causative agent place of injury circumstances under which it took place type of first aid treatment, and the time lapse from injury to hospital admission Other significant factors are the patient s mentality age dominant handedness previous injury occupation and reaction toward his injury The knowledge of a patient s occupation is essential since the functions of a laborer clerk and model are quite different. Some desire functional improvement whereas others are interested in cosmetic results Also the hobbies and athletic tendencies of the patient should be taken into account since an operation that would satisfy a

wound is draped for operation

Debridement is done with removal of all dead and devitalized tissue The more experience one obtains in debridement the lower the infection rate will be Ellis[7] finds that when setting up an assembly line technique for the treatment of injured hands the infection rate is always higher in the first group of cases treated by a new group of students and doctors than later in their experience

Following debridement repair of the injured deep structures is undertaken Although detailed treatment of these will be given in subsequent chapters a few general remarks are in order As a general rule except with gross contamination fractures and dislocations are reduced vessels ligated and nerves sutured The main problem concerns tendon injuries and the decision to perform primary or delayed suture This depends upon the type of injury cleanliness of the wound and the time interval between injury and treatment.

When *incised* wounds are clean primary wound closure may be done within twenty four hours if there are no signs of inflammation Tendons outside of sheaths may be repaired up to twenty four hours but tendons inside of sheaths should not be repaired beyond twelve hours When incised wounds are dirty and debridement is good the wound may be primarily closed up to twelve hours No intravaginal tendon repair should be attempted but extravaginal repair is possible within six hours If debridement is incomplete delayed wound closure is performed

Avulsed clean wounds may be closed within twelve hours if there is no sign of inflammation Intravaginal tendon repair should not be done but extravaginal repair is possible up to ten to twelve hours When avulsed wounds are dirty but debridement complete, primary closure may be done within twelve hours with extravaginal tendon repair performed up to six hours If debridement is incomplete delayed wound closure is performed

Crushed clean wounds may be primarily closed within twelve hours if no inflammation is present and extravaginal tendon repair possible within ten to twelve hours Intravaginal repair should not be attempted Crushed dirty wounds with complete debridement may be closed within eight hours with extravaginal

patient's occupational requirements but which would prohibit him from playing golf might seriously influence his opinion of the result[8]

Prior to operation a detailed examination of the hand and arm is begun with a sterile dressing applied to the wound Examination should include testing for motion and sensation There are several clinical pitfalls which should be avoided For example, if the hand is painful a particular movement often is absent even though the structure is intact. On the other hand a partially lacerated tendon could function if no pressure was exerted on it but would pull apart with the slightest exertion Substitute motions are often a source of difficulty For instance flexion of the metacarpophalangeal joint of the thumb by the short flexor might lead to confusion when diagnosing a lacerated flexor pollicis longus The type of wound should be noted since it is well known that incised wounds heal better than crushed or avulsed ones Proper x rays are taken to insure correct evaluation of fractures

Patients with major injuries are operated on under general or regional anesthesia All injuries are repaired in a bloodless field obtained by application of a tourniquet to the upper arm after the arm has been made ischemic by elevation or wrapping with an elastic bandage During the operation the tourniquet should be released every hour to prevent ischemic changes in the nerves or other soft tissues. Bruner[6] emphasizes the various safety factors in the use of a pneumatic tourniquet. He believes that younger people can tolerate ischemia longer than older people that people having a rheumatic diathesis become stiffer sooner than others that ischemia due to crushing or destruction of blood vessels may make the use of a tourniquet hazardous.

The surgeon dons a cap and mask, scrubs in the usual fashion and puts on a sterile gown and gloves The injured hand is shaved from the elbow to the fingertips and washed for twenty minutes with soap Care must be taken to avoid scrubbing the wound The surgeon changes gown and gloves (if there is another surgeon on the case he takes over) and the wound is irrigated with saline solution the amount depending upon the degree of injury Following this the surgeon changes gown and gloves and the

8 Zackariae, L., and Zackariae, F.: Hydrocortisone as an adjunct in the treatment of posttraumatic stiffness of the hand. *Acta orthop. scandinav.*, 24:50-61, 1954.

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tendon repair done up to six hours If debridement is incomplete delayed wound closure should be performed Using this method of therapy Flynn [2] reports a sepsis rate of 1 47 per cent in 612 cases seen over a five year span

After the wound has been closed the hand is placed in a plaster of Paris cast or pressure dressing in a position of function when ever possible depending upon the structures involved Tetanus antitoxin or tetanus toxoid is given depending upon the previous immunization of the patient. If there is any doubt, both methods are used Penicillin has become routine for the first few post operative days but there is a grave question as to the value of this procedure The patient is hospitalized for all serious injuries until one is sure that infection is not present in the wound

The after care of hand injuries will depend upon the structures involved but generally after the sutures are removed and the bone stabilized active and passive motion is begun Whirlpool baths and soaks may be used to reduce pain in the hand so that move ment is facilitated Several authors use cortisone and allied steroids as an adjunct to the treatment of post traumatic stiff ness [6,10] However the value of this procedure is questionable Barden [3] points out an important point in that the rehabilitation should not only relate to the hand but also to the patient s psychological approach to his illness An attempt should be made to get the patient back to work as soon as possible

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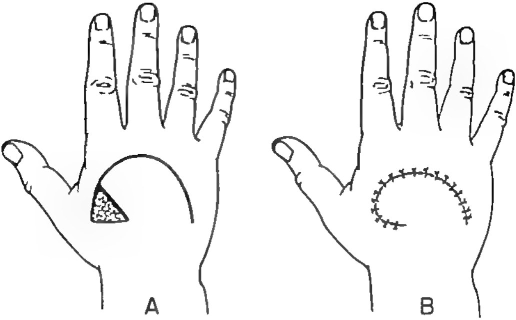

Figure 55 Rotation flap

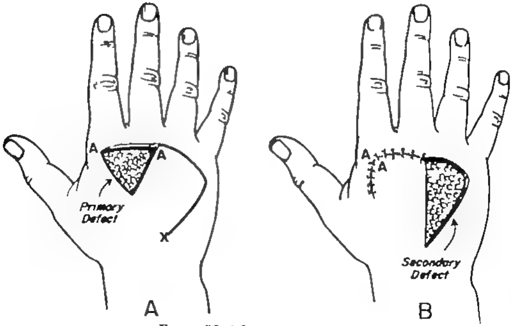

Figure 56 Advancement flap

CHAPTER 7

SKIN

LACERATION

After careful debridement and cleansing of the wounded area early coverage with skin is essential to prevent subsequent scar tissue formation in the hand The skin edges must be brought together without tension and handled as atraumatically as possible In order to bring the skin together without tension it may be necessary to undermine large areas

If there is skin loss various combinations of free skin and flap grafting may be necessary Local skin flaps can be used for small defects. Their general purpose is to relieve tension on the suture line to insure that vulnerable structures such as bone tendon or nerve are covered by skin and fat, and to alter the site or direction of potential scar or tension lines An excellent study has been presented by Rank and Wakefield [1]

When designing local flaps it is well to remember that the triangle is the basis for such flap design so that wounds should be trimmed or shaped in this fashion The simplest flap is a rotation flap whereby the incision is lengthened from one apex of the triangle curving toward a line projecting from the opposite base of the defect (Fig 55) The length of this incision depends upon the anatomical details of the region and the elasticity of the skin This flap is undermined and sutured to the other side of the wound so that the tension is distributed over a wider area

Where the rotation flap is not feasible an advancement flap may be executed The defect is covered by a swinging local flap and the resulting donor site is covered by a split thickness graft (Fig 56) In planning such a flap it should be remembered that the hinge of the graft is the base of the flap most distant from the defect As can be seen by the diagram A X should equal A X

When defects are so large that local flaps cannot be used

other types of grafting must be performed If the underlying structures are not vital ones the defect may be covered with a split thickness graft However if the graft has to be placed on the palm of the hand or covers tendons or nerves it is best to use a broad based flap graft

The flap graft is of great value in fingers for covering defects on adjacent surfaces A cross finger flap may be of value when it can be raised from the lateral surface of one finger and transferred to the volar surface of another the resulting donor site being closed with a split thickness graft [2] For other areas it is necessary to use either the opposite forearm (Fig 57) or the chest or abdomen depending upon the need and situation A cross arm bridge flap often is useful for repairing such defects (Fig 58) If fingers are to be amputated they may be fileted and the soft tissue used as flap grafts [3]

In severe avulsed wounds the flap must be carefully observed to be sure that it is viable It is necessary to remove all subcutaneous tissue and replace it as a full thickness graft However if the flap has been crushed it should be discarded and a skin graft used

No matter how large the skin defect it must be closed even if a split thickness skin graft is all that is possible Thus the patient can be prevented from developing contractures and stiffness of the hand due to an exposed wound [4,5] Subsequent excision can be done with the proper resurfacing

AMPUTATION

Every effort should be made to maintain the length of the thumb index and middle fingers This is not quite as essential with the ring and fifth fingers The nerve ends always are searched for and cut back sufficiently so that they will not become incorporated in the scar If approximately a third of the nailbed remains it is important to remove this since the resulting nail

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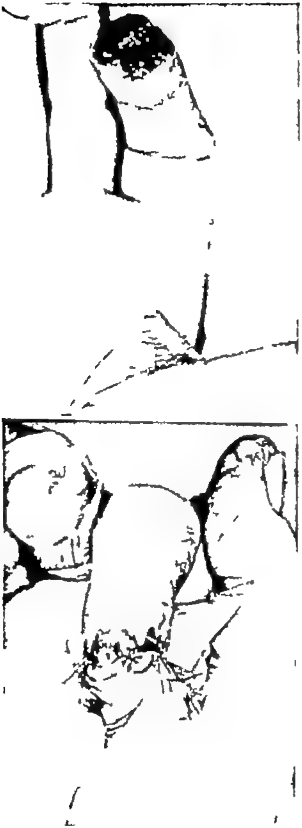
Figure 57 (Top) Finger flap graft using opposite forearm. (Courtesy Dr Anthony Zovickian)

Figure 58 (Bottom) Cross arm bridge graft. (Courtesy Dr Anthony Zovickian.)



will never be satisfactory and may lead to a deformed and painful stump

If very small portions of the fingertip are removed no treatment may be necessary other than re-suture or permitting the wound to heal by secondary intention When larger areas of the fingertip are removed but do not include bone a split thickness skin graft usually is successful and functions well

When the amputation involves the bony phalanx, split thickness grafts may be unsatisfactory since they become adherent to the bone and result in a sensitive fingertip In this case there are several procedures possible such as full thickness grafts, plastic repairs and the use of skin flaps

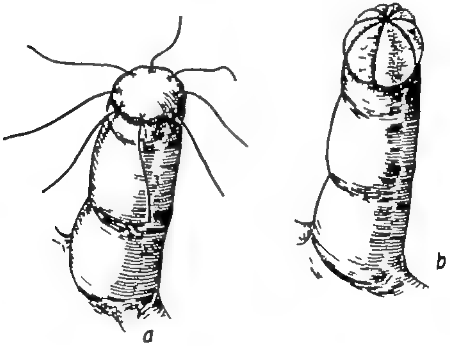


Figure 59 Method of applying pressure to fingertip skin grafts. (a) Sutures are left long (b) they are tied over foam rubber

Full thickness grafts have been satisfactory in my experience. Usually they are taken from the forearm in a size sufficient to

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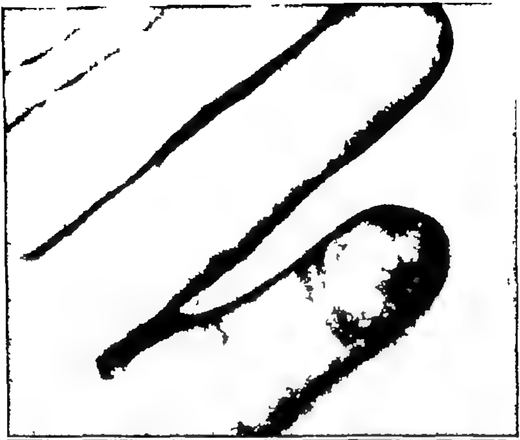
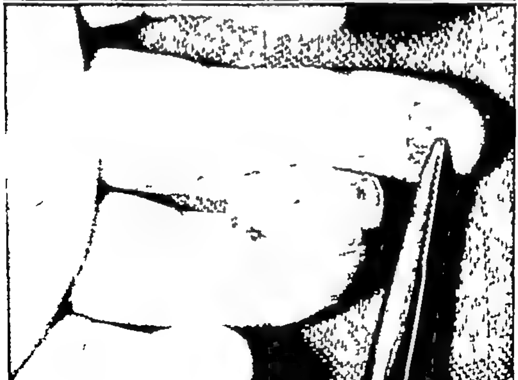
Figure 60 (Top) Amputation of fingertip with loss of pulp (Courtesy Dr Anthony Zovickian.)

Figure 61 (Bottom) Thenar flap graft elevated and sutured into fingertip defect. Donor site covered with a split thickness graft.

match the defect and are placed on the fingertip after the subcutaneous tissue has been removed The ends of the suture are left long and tied over a piece of foam rubber to insure a pressure dressing (Fig 59) These grafts do not shrink and in time even become slightly movable over the underlying bone Stenberg,[6] had only one failure out of forty such cases Robins [7] suggests the use of a post-auricular skin graft An area of skin the size of the defect is taken from behind the pinna extending on to the mastoid process Every trace of subcutaneous tissue is removed and the skin placed on the amputation site and mobilized as was previously mentioned He reports thirty five successful takes with forty two such grafts

Various plastic repairs of the fingertips have been advised and successfully used by some authors Riess [8] reported on thirty cases in which he used Erler s plastic repair of the fingertip whereby a triangular flap is formed with the point at the finger crease and the base at the skin wound The incision is carried through the skin and then this triangular portion of tissue still attached to the underlying blood vessels and fascia is advanced to cover the defect. The resulting skin edges are then closed He found this type of flap to be useful in injuries of the distal fold of the end joints but found that they were unsuccessful in stumps when only a small portion of the nail remained. Kutler [9] describes a modified plasty where two triangles are formed on either side of the injured finger which are advanced to cover the end of the finger

When more serious injury of the end joint occurs and there is a great loss of pulp (Fig 60) it is necessary to replace skin and subcutaneous tissue on the defect by a skin flap One method is the raising of a flap from the thenar eminence suturing it to the defect, and repairing the defect on the thenar eminence with a split thickness graft (Fig 61)

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Figure 62. (Top) End result of thenar flap graft.

Figure 63 (Bottom) Cross finger flap covering amputated fingertip (Courtesy Dr Anthony Zovickian)

The index finger opposed to the thumb is essential for the pincer movement If the index finger is amputated at any point proximal to the proximal interphalangeal joint this function is interfered with and it will be necessary to amputate the index ray In cases where the finger length may be sufficient—but the finger is so damaged that its tip cannot be opposed to the thumb—it may rob the adjacent fingers of their combined function and ablation of the index ray again will be necessary[13] The base of the metacarpal is not included when removing the index ray so as not to interfere with the insertion of the extensor carpi radialis longus If possible the tendon of the first dorsal interosseous is isolated and inserted onto the tendon of the second dorsal interosseous The digital nerves are carefully isolated ligated and buried to prevent amputation neuroma difficulties

Rarely the cosmetic appearance of the hand may be more important than the two previously mentioned factors If there are index or fifth finger stumps it may be necessary to resect the ray and cut the metacarpal bone obliquely to give a smooth contour to the hand. With amputation of the third and fourth fingers it sometimes will be necessary to remove the metacarpal and restore the continuity of the transverse intermetacarpal ligament. Thus this will prevent a rotation deformity of adjacent fingers and such hands are cosmetically more acceptable

The immediate grafting of an amputated finger is suggested by Gillies and Reid[14] who report several cases The principle is to discard the skin envelope and utilize the bones and tendons of the severed digit, maintaining viability by providing them with an entirely new blood supply The skin of the severed digit is dissected off and the nail avulsed The raw area of the stump is enlarged by trimming back the skin and suturing the tendons of the severed portion to the corresponding tendons of the stump The attached denuded finger now is inserted into a subdermal pocket beneath the clavicle in the male or in the abdominal wall in the female The skin edges of this pocket are sutured to the skin of the stump in a circumferential manner The flap can be divided after a suitable period and the grafted finger now covered with new skin is freed from its pocket.

Approximately fourteen days later the pedicle is cut and sutured in place and if necessary at another stage the flap is re shaped on the finger This is a very satisfactory method of re pulping a fingertip (Fig 62) The only disadvantages are a scar on the tactile area of the palm and an occasional contraction of the finger which has been held in a flexed position for many weeks

Another modification much in vogue is the use of cross-finger flaps A flap may be raised from the dorso-lateral surface of an adjacent finger to cover a fingertip defect (Fig 63) The donor site can be closed with a split thickness graft. The flap is made one-quarter larger than the defect and can be based proximally distally and longitudinally [10] When more than one fingertip has to be re pulped abdominal flaps are necessary

When deciding upon the type of fingertip repair the age of the patient must be considered Grafting of fingertips prolongs healing time and the elderly patient may be better off if the phalanx is trimmed back and a long volar flap sutured to the dorsum The patient will return to work sooner get his finger moving quicker and may in the long run have a better hand

A perenial question is—what to do with the fingertip that is brought in with the patient Often it is felt that is is useless to re apply these but occasionally there are brilliant results obtained so that one is tempted to restore the phalanx.[11]

Useless fingers are amputated conserving as much length as possible The over all picture in the hand should always be considered since often the skin can be removed from the finger and used as a filet to cover a defect in the palm or other surface of the hand.

The decision as to what level the finger should be amputated will depend upon the three main functions of the hand grasp pincer and cosmetic. To obtain a good grasp all four knuckles should remain intact with a strong opposable thumb Therefore, stumps of the proximal phalanges should be left in order to give a working man a good grasp Also the heads of the third and fourth metacarpals are essential in maintaining the breath of the palm and therefore should be left intact [1]

CHAPTER 8

TENDONS

HEALING

After cut tendon ends are approximated there is an outpouring of fibrin during the first two days By the fifth day fibroblasts grow from the connective tissue elements of the tendon into this mass of fibrin They produce primary fibrils which have their origin inside the fibroblast cytoplasm The fibrils mature and fuse forming longer threads and eventually well recognized fibers The primary fibrils are of the order of about 100-200A units in width They have been identified by the electron microscope not only at the bundles at the surface of the fibroblasts but also within the cytoplasm in the marginal region of the cell[1] During the third week the formation of collagen fibers bridges the gap between the tendon ends The edema and vascularity at the tendon junction gradually diminish so that by the end of the fourth week there is good strength at the junction site

Nichols *et al*[2] made a study of the alteration of the blood supply of flexor tendons following injury and recognized that the blood supply of the tendon comes from five sources (1) the musculotendinous junction of the forearm (2) the mesotendons in the carpal canal (3) the lumbrical muscle (4) the proximal ends of the digital sheath (5) the vessels contained within the vincula longus and brevis of the tendons These authors emphasize that tendon injuries which occur in sheaths appear to show an increase in vascularity with degeneration of the normal histologic pattern more severe than in tendon injuries outside the sheath and believe this may be due to an interference with the venous return The poor blood supply of tendons in the digital sheath (no man s land) is an added factor responsible for poor healing of tendons in this area

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METHODS OF REPAIR

Once the decision is reached to do a primary tendon suture the tendons must be adequately exposed Occasionally the tendon repair may be posible through the initial wound but in most cases the existing wound will have to be enlarged A comon mis take of the beginner in this field is to waste time trying to operate through an inadequate incision As soon as the damage is assessed the original incision should always be enlarged Fruitless time must not be lost attempting to find structures by inserting hemostates along tissue planes in the attempt to find the tendon ends If the tendons cannot be found after extension of the wound an accessory incision is made proximal to the original incision the proper structures isolated and found and rerouted along their normal channel for final repair The incision is planned so that the tendon is overlain by a flap of subcutaneous tissue and skin [11] Longitudinal incisions on the finger should not be placed volar to the lateral limits of the flexion creases Lateral incisions along the index finger and thumb and medial incisions along the little finger may be extended along the lateral and medial borders of the hand respectively Incisions in the palm should be transverse Enlargement of transverse incisions should be made by means of longitudinal incisions proximally and distally from either end of the original wound

There are numerous methods of tendon repair but those used most frequently are the zigzag silk and stainless steel wire pull through sutures of Bunnell The Bunnell zigzag suture is inserted by threading a 000 silk suture on a short small needle transversely through the tendon one centimeter from the end which has been grasped with a straight hemostat Threading this suture with two needles it is criss-crossed twice across the tendon coming out adjacent to the hemostat (Fig 64A) These sutures are passed through the tendon in different planes so that each one incorpor ates various fiber bundles (Fig 64B) In this way the longitudinal pull of the suture is partially converted to a transverse one thus allowing greater traction The end crushed by the hemostat is carefully removed with a sharp knife and the suture pulled taut (Fig 64C) The distal tendon is held similarly with a hemostat

One serious problem in tendon repair is adhesion formation around the tendon which prevents its movement. Wrapping the tendon with various substances has been attempted to prevent this Nichols [3] reports no special advantage to the use of a gelatin sponge As a matter of fact it produces excess fibrosis at tendon junctures and apparently autolyzes tendon grafts Weckess *et al* [4] experimented with various substances such as human fibrin film bovine fibrin film cellophane and autogenous fascia and found that human fibrin film was most effective in preventing adhesions. However he noted that these substances may interfere seriously with the nourishment of tendons around which they are wrapped. Farmer [5] used cellophane in several clinical cases but found no particular advantage Gonzalez,[6] found that the use of polyethylene tubes could prevent adhesions around a tendon anastomosis however the tendon required approximately forty days for sound healing since the film wrapped around the tendon interfered with the blood supply at the tendon junction This would limit the procedure in humans as forty days of immobilization would stiffen the finger joints so that function would be greatly limited.

The action of cortisone in preventing adhesions around tendon repairs has been studied with no evidence that it decreased adhesion formation [6,7] Parenteral cortisone was tried in tendon suturing in dogs with the result that end to-end healing was not prevented but the tendon was 40 per cent weaker than the controls [8]

Another approach to the repair of the gliding tendon has been the attempt to produce an artificial tendon sheath by introducing various tubular structures along the course of the subsequent reconstruction which would stimulate the development of a smooth well lubricated synovial sheath lined channel This was accomplished by inserting a polyvinyl chloride resin flexible tube with the result that a tendon sheath was created which seemed to have a good gliding surface [9] The lining of these canals were shiny smooth and well lubricated Microscopically the sheaths were lined on their inner surfaces by flattened mesothelial like cells Palazzi [10] had an unsatisfactory experience with the use of stainless steel tubes which were removed in three weeks

don is removed and the tendon slid along the suture so that there is a close approximation with the opposite tendon end (Fig 64E) A stitch transversely placed across the tendon is made and the two ends sutured At the conclusion of this procedure the tendon edge should be well approximated and the tendon slightly wrinkled (Fig 64F) since there is a tendency for the tendon to slide along the suture for a few millimeters when muscle contraction takes place

Bunnell s steel wire pull through suture is performed using a #32 stainless steel wire suture which has a needle on each end (Fig 65) Each is criss-crossed through the proximal tendon twice

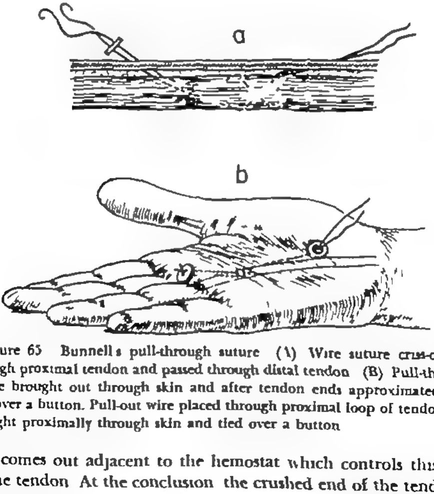

Figure 65 Bunnell s pull-through suture (A) Wire suture criss-crossed through proximal tendon and passed through distal tendon (B) Pull-through suture brought out through skin and after tendon ends approximated it is tied over a button. Pull-out wire placed through proximal loop of tendon and brought proximally through skin and tied over a button

and comes out adjacent to the hemostat which controls this end of the tendon At the conclusion the crushed end of the tendon is removed by sharp dissection and the wire suture pulled into place The two needles are passed through the cut end of the distal tendon and brought out about a centimeter distally The two ends of the tendon are pushed together and two ends of the

and the two needles of the suture inserted extremely close to the hemostat into the tendon and criss-crossed twice across the tendon (Fig 64D) With sharp dissection the crushed end of this ten-

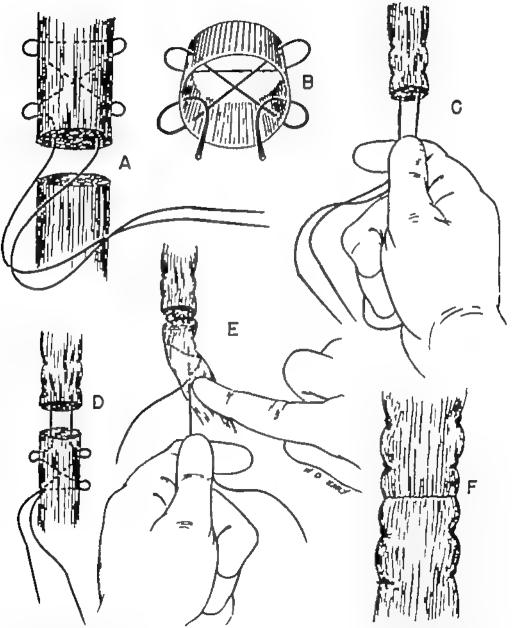

Figure 64 Bunnell's zigzag suture (A) Suture criss-crossed twice across proximal tendon and coming out through cut tendon end, (B) Sutures passed through different planes to incorporate various fiber bundles (C) Suture pulled taut (D) Suture criss-crossed through distal tendon in similar manner (E) Suture pulled taut, (F) Suture tied.

tendons to the tunnel with marked limitation of motion of the finger When the flexor digitorum sublimis is divided it is excised distally to a few millimeters from its attachment to the middle phalanx and proximally so that it will retract to the palm The suture of one slip of the sublimis tendon should not be attempted If both tendons are involved the sublimis is cut away as previously described and the profundus sutured The digital sheath in the region of the tendon junction is completely excised as suggested by Mason[11] Primary repair of the profundus tendon in this area should be done only in clean incised wounds relatively soon after injury In all other cases there should be simple skin closure with subsequent tendon grafting Some surgeons are attempting a primary tendon graft as an initial treatment.[15]

Duncan[16] made an interesting observation concerning these injuries If they were lacerated while the interphalangeal joints were flexed and then repaired the suture line can be moved distal to the original skin and tendon sheath laceration by extending the interphalangeal joints and flexing the metacarpophalangeal joint and wrist. In this manner the tendon suture is moved away from the scar tissue which will unite the original wound and primary repair is apt to be more successful On the other hand if the laceration occurred while the interphalangeal joints were extended it is impossible by joint positioning to move the tendon suture away from the original scar In such cases failure is so certain that Duncan uses a tendon graft.

Injuries to the flexor profundus tendon over the *middle phalanx* give better results than over the proximal phalanx. Even if the repair fails there should be sufficient movement of the metacarpophalangeal and proximal interphalangeal joints to insure a useful finger It may be advantageous in some cases to excise the distal portion of profundus tendon and advance the proximal end into the distal phalanx of the finger In this way there will be no suture line in the digital tunnel

Injuries of flexor tendons of the *distal phalanx* usually heal satisfactorily after repair with no other difficulty than limitation of motion of the distal interphalangeal joint

The *flexor pollicis* tendon is a somewhat different entity than the flexors of the fingers Suture at the interphalangeal joint

wire suture are threaded on the same needle and brought out through the skin They are tied over a button with sufficient tension to hold the tendon ends together Before this suture is completed a loop of wire is placed around the proximal loop of the tendon suture threaded on a single needle and brought out proximal to the incision in a position where the pull on the tendon will be at an obtuse angle It is held in place with a small button or split BB shot. When the wound has healed the suture on the distal button is cut and removed by pulling on the proximal wire loop

Other types of tendon suture are those utilizing a stay-suture principle a modified mattress suture and a barbed braided tantalum pull-out suture [10-14] I routinely use the Bunnell zigzag silk suture technique in all tendon anastomoses and reserve the *pull-out technique for insertion of tendon into bone I believe that* failures following tendon repair are not the fault of the type of suture but are due to infection poor approximation of tissues, adherence of tendon suture to dense unyielding fascia and slight pulling apart of the suture line

Flexor Tendons

Flexor tendons cut at the *wrist* usually heal satisfactorily when carefully sutured One s anatomical knowledge should be expert since occasionally the median nerve is sutured to a tendon Another error is failure to recognize that the flexor profundus tendons of the third fourth and fifth fingers are still fused at this level and much time is wasted looking for proximal profundus tendons to match up with the distal profundus tendons.

Flexor tendons repaired in the *palm* proximal to the digital tunnel usually yield satisfactory results There is plenty of gliding tissue in this area and to further enhance this the lumbrical muscle should be sutured around the anastomosis site

Flexor tendons lacerated along the *proximal phalanx* have a universally poor prognosis This no man s land or danger zone is the area from the palmar crease to the proximal interphalangeal joint where the two closely adherent tendons glide beside each other through the narrow fibrous digital sheath Attempts at repairing these tendons result in adhesion of the

phalanx it will be necessary to use a pull through suture technique To permit strong bony union one should turn up a bone chip or drill a small hole at the insertion bringing the tendon into this area of freshened bone One of the problems of repair in this region is that the tendon adheres to the underlying joint and adequate flexion is not possible To prevent this various methods have been devised such as rotating a soft tissue flap to cover the raw surface of bone or applying a free paratenon graft under the repaired tendon [18]

AFTERCARE

Repaired tendons are immobilized with a plaster-of Paris cast in a position which permits a minimum of tension on the suture line while avoiding maximum strain on the involved joints Flexor tendons are immobilized for three weeks in a position of slight wrist flexion with flexion of the involved fingers Extensor tendons over the dorsum of the hand and phalanges usually are immobilized for four to five weeks since they may be stretched by the strong flexor pull if immobilized for less time Extensor tendons on the back of the hand and over the proximal phalanx are immobilized with the wrist dorsiflexed about 15 degrees and the metacarpophalangeal joints fully extended with slight flexion in the proximal interphalangeal joints Lacerations over the proximal interphalangeal joints are immobilized with the proximal interphalangeal and metacarpophalangeal joints extended If the lateral bands have been cut it will be necessary to put the distal joint in extension also Lacerations of the extensor tendons over the distal interphalangeal joint are immobilized with the proximal interphalangeal joint flexed and the distal joint extended

As a general rule only injured digits are immobilized In children and irresponsible patients the plaster cast is made sufficiently strong to prevent breakage

When the cast and sutures are removed physiotherapy is instituted Although heat is of benefit the best physiotherapy is active and passive motion of the involved joints until there is a maximum return of function Other joints of the involved extremity are similarly treated Particular attention is directed to the shoulder and motion is begun even while the plaster-of Paris

or close to it gives a good result and lacerations over the proximal phalanx can be advanced into the distal phalanx to give good function. The problems with the digital sheath are the same as with the fingers but there is one anatomical difference in that the tendon origin of the flexor pollicis longus may be released and the entire tendon slid along the muscle belly so that the distal end of the tendon is advanced into the distal phalanx.[17,19] Blum[18] applied this technique to tendon repair in the fingers.

Extensor Tendons

Extensor tendons of the dorsum of the *wrist* are repaired by the method described for flexor tendons. While it is true that the vincula often may splint adjacent tendons, it is best not to rely on them particularly if more than one tendon is involved. If the tendons are cut as they pass under the dorsal retinaculum a portion of this is removed to allow free movement of the repaired tendon. If possible some of the retinaculum is left to prevent subsequent prolapsing of the tendon on dorsiflexion.

The extensor tendon over the *metacarpophalangeal joint* has a close relationship with the underlying joint capsule and often a simple mattress suture with splinting in extension is sufficient for repair.

When the extensor tendon is cut over the *proximal phalanx* it can be sutured with mattress sutures and positioning of the tendon will be possible with the aid of splinting. If the lateral bands are cut they should be similarly sutured.

The extensor tendon at the *proximal interphalangeal joint,* when severed gives rise to the typical buttonhole deformity with flexion of the proximal interphalangeal joint and extension of the distal interphalangeal joint. Repair of this laceration is not easy since it often is difficult to suture the central slip to the proximal phalanx. If the lateral bands have retracted laterally they will have to be resutured in a proper position but they should not be brought dorsally over the joint or else there will be an extension contracture of the finger.

Extensor tendons cut over the *distal interphalangeal joint* produce the typical mallet finger and the tendons should be resutured. When the tendon is cut flush with the base of the

interosseous muscles be completely put to rest by immobilizing the hand with the metacarpophalangeal and proximal interphalangeal joints flexed and the distal interphalangeal joint extended

The standard method of treatment is to immobilize the finger with plaster-of Paris keeping the distal interphalangeal joint in hyperextention and the proximal interphalangeal joint in flexion Pratt [21] states that this position can be maintained by threading a Kirschner wire through the distal middle and proximal phalanges

Various authors keep the proximal interphalangeal joint mobile by applying a splint over the distal interphalangeal joint Ledergerber [22] uses a small wooden splint in which two holes are bored through the end of the splint and fingernail Through these are placed a suture which is tied This splint extends from the finger tip to the proximal interphalangeal joint and is held in place with adhesive tape for six weeks This provides a useful splint since the patient can use his finger while the splint is in place A modification is presented by Mason [23] who uses the Enid splint which consists of a wooden tongue depressor cut from the proximal interphalangeal joint to the distal phalanx Between the splint and the end of the finger is inserted a wedge shaped piece of cork, with its thick end distally which is fixed to the rounded end of the tongue depressor with glue The splint is applied so as to hyperextend the terminal interphalangeal joint and is bound in place with strips of adhesive tape after the dorsum of the finger has been protected with a strip of felt Thus the proximal interphalangeal joint is left free The splinted finger can be protected with a rubber finger-cot. Fifty two patients were followed twenty-six treated by the usual technique and twenty six with the Enid splint, and he found that after six weeks of immobilization half of each group obtained full extension of the terminal joint The value of this was that although the end results were the same the patient could work while wearing the Enid splint Mommsen [24] utilizes a method of relaxing the lumbrical and interosseous muscles He places a dorsal plaster slab on the hand from the knuckle up toward the elbow which is kept in place with a circular plaster around the wrist and forearm The finger is held with the metacarpophalangeal and proximal interphal

cast is on the hand Too often the hand injury recovers but the limitation of motion of the shoulder joint is severely incapacitating

RUPTURED TENDONS

Rupture may occur from sudden strong stretching of a normal tendon from a less severe stretch of a tendon weakened by disease or constant motion over an irregular rough bone surface

Baseball Finger

A sudden forced flexion of the distal interphalangeal joint will produce an avulsion of the extensor tendon from the distal phalanx manifested by a marked flexion deformity of the distal phalanx (Fig 66) This is known as baseball or mallet finger

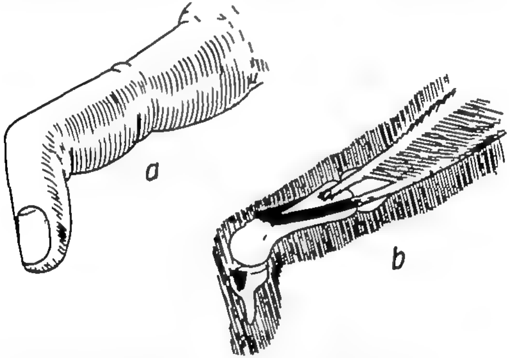

Figure 66 . Baseball or mallet finger (a) characteristic deformity due to (b) rupture of extensor apparatus over distal interphalangeal joint.

The essential therapeutic principle is immobilization with the distal interphalangeal joint hyperextended for approximately five to six weeks In addition the proximal interphalangeal joint must be kept either flexed or mobilized to prevent stiffening of this important joint. Mommsen[20] suggests that the lumbrical and

to slide laterally over the interphalangeal joint This produces a characteristic deformity with flexion of the proximal interphalangeal joint and extention of the distal interphalangeal joint (Fig 67) Conservative therapy consisting of immobilization in

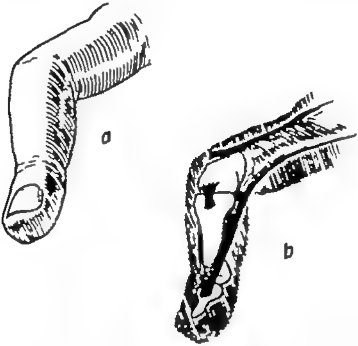

Figure 67 Buttonhole rupture of extensor tendon (a) characteristic deformity due to (b) tear of central tendon permitting lateral bands to slide over proximal interphalangeal joint.

a plaster cast with the metacarpophalangeal and proximal interphalangeal joints extended may be successful but usually such a finger will require operation for reinsertion of the communis tendon into the middle phalanx It may be impossible to bring the extensor ends together in which case a graft is indicated Dorsal displacement of the lateral tendons must be avoided to prevent extention contracture

Rupture of the Extensor Pollicis Longus Tendon

The extensor pollicis longus tendon is long and thin and slides through a groove in the distal end of the radius beside Lister's tubercle Since first reported by Duplay[20] there have been numerous reports of this rupture In the early German

angeal joints flexed and the distal joint extended by a band of adhesive tape spread around the hand A piece of felt prevents the finger from producing a pressure necrosis in the palm.

It is recognized that no method of treatment is completely successful Kirkham [24] instructs the patient to hyperextend the distal joint by pressure of the affected finger against the thumb This can be carried out on multiple occasions throughout the day giving an end loss of not more than a few degrees at the terminal joint During this time the patient continues to work

When there is a chip fracture of the distal interphalangeal joint one should not immobilize in extension since I have seen several fingers become fixed in this position and become more useless than with the original deformity When there is a chip fracture, the finger is maintained in a slight position of flexion

When such injuries are seen late it usually is necessary to operate and suture the extensor tendon into the distal phalanx using a wire pull-out technique Sometimes the only procedure that will be necessary is a reefing of attenuated extensor tendons At other times there may be such extensive loss of the extensor tendon that it will be necessary to put in a tendon graft. Nichols [25] suggests a repair for such injuries in which he uses as his tendon graft a split portion of the palmaris longus approximately three to four inches long about the thickness of No 1 catgut The tendon graft is first anchored in the distal phalanx in the stump of the old tendon or through a side to-side drill hole in the bone. It is passed back across the joint threaded through the sound tendon proximal to the tear and woven back to the distal phalanx. This is sutured in place with mattress sutures of fine silk. In cases where injury to bone has caused adhesions to tendons some sliding material is interposed between the tendon and bone He wisely cautions that if the original injury was infected a long waiting period should be enforced before the secondary operation is performed In ordinary circumstances the repair is done one month after injury

Buttonhole Rupture of the Extensor Tendons

The extensor communis insertion into the middle phalanx may be torn permitting the lateral bands of the extensor mechanism

fracture deformities[38,39] Treatment consists of repair of the tendon or suture of the distal tendon to an adjacent functioning extensor tendon

A recurrent dislocation of the extensor tendons may arise from trauma which produces a tear on one side of the extensor aponeurosis and permits the extensor mechanism to dislocate to the opposite side of the finger Wheeldon[40] uses the ingenious method of repairing this defect by swinging a junctura tendinum attached to one finger down to the line of the torn aponeurosis The hand is immobilized in a plaster splint for three weeks in a position just short of full extension There was no sign of recurrence Bunnell[41] threaded a length of palmaris longus tendon across the extensor tendons and sutured the graft midway between each tendon Fitzgerald[42] and Cutler[43] used a strip of fascia for a similar purpose

Flexor Tendons

Flexor tendons similarly may rupture due to fracture disunion or arthritis James[44] reports pathologic ruptures of the tendons of the flexor pollicis longus and flexor profundus to the index finger due to fraying from continued motion across the semilunar bone affected with Kienbock s Disease The tendon had to be repaired with a tendon graft Broder[45] reports the case of a seventy-one year old man who had a spontaneous rupture of numerous of the flexor tendons in the hand due to fraying by moving over a volar bony projection of the distal end of the radius The profundus tendons were sutured and the patient recovered. Drew[46] reports an unusual case of a thirty-one year old woman who suffered spontaneous rupture of the profundus tendon of the ring finger At operation it appeared to be an ischemic necrosis probably due to singular or repeated blows to the palm

I have recently seen a spontaneous rupture of both flexor tendons of the right index finger in a thirty-eight year old woman At operation there was found a mucinous degeneration of the tendons No obvious cause could be found She is now developing a similar condition in the left ring finger

literature the spontaneous rupture of this tendon occurred frequently in drummer boys and was known as drummer's palsy It remained for Dums[27] to show that it was not a palsy but a spontaneous rupture of the tendon due to chronic tenosynovitis. Recent references to this condition associate it with a roughening of the groove in the radius due to Colles fracture.[28-33] Levine and Schneider[34] report a rupture following a fracture of the carpal navicular bone However a fractured bone is not necessary and arthritis may predispose to such conditions Smith[29] believes that some ruptures may be due to an aseptic necrosis due to interference with the blood supply of the tendon at the distal end of the groove in the radius

There is a sudden sensation of something giving way or a snapping on the back of the wrist followed by inability to straighten or lift the thumb actively as compared with the normal thumb In Smith's[29] series it occurred in one out of every 268 Colles fractures Repair is done by direct suture whenever feasible but, if not, there are alternative methods Smith emphasizes the important oblique adducting pull of this tendon as well as its extension of the distal phalanx He believes the best repair to be suture of the distal portion of the extensor pollicis longus to the extensor carpi radialis by an end to-end suture The hand is placed with the thumb in full extension and elevated dorsally The cast can be removed at the end of two to three weeks and active motion begun Trevor[30] states that the tendon can almost always be sutured even with an interval of five months between rupture and suture He uses a strong nylon thread which is crisscrossed through the tendon and brought through the tendon ends He has had success even though the tendon ends have not been united by the suture An alternative method is suture of the extensor longus pollicis tendon to that of the extensor indicis proprius In cases in which none of these methods are possible Furlong[35] suggests that a tenodesis between the distal ruptured tendon and the radius gives a good functional result.

Extensor Communis Digitorum

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CHAPTER 9

NERVES

HEALING

Following nerve injury the distal portion of nerve undergoes Wallerian degeneration in which the axis cylinder medullary sheath and the sheath of Schwann cells degenerate Similar changes occur in the proximal nerve up to the first node of Ranvier together with changes in the cell nucleus in the spinal cord

Shortly thereafter the axis cylinders begin to proliferate and emerge from the proximal nerve end and become emeshed with an overgrowth of connective tissue from the perineurium endoneurium epineurium and the sheath of Schwann producing a nodule called an amputation neuroma At the distal end of the nerve there is some tendency for the connective tissue to grow and form a distal glioma If the freshly incised nerve is sutured or if in an old injury the scarred portions are cut away and the ends approximated normal nerve healing will occur The neurofibroblasts proliferate and bridge the gap between the nerve ends and accompany and ensheath the regenerating nerve fibers down the distal nerve [1] The Schwann cells play only a small part in the regeneration of nerve The nerve fibrils continue to grow down the distal nerve in the meshes between the cells of the degenerating distal nerve. These neurofibrils grow at the rate of approximately one inch per month

The first clinical manifestation of regenerating nerve is the occurrence of paresthesias on percussing the nerve As this is done beginning distally and proceeding proximally a point will be reached at which the patient feels a tingling or buzzing sensation with radiation of sensation down to the involved hand area The advancing edge of this sensitive area in the nerve is measured at monthly intervals using some bony prominence as a

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they may save many months of futile waiting for clinical manifestations to return in cases where re-operation on a nerve or tendon transfer is contemplated. Rarely a herpes-like lesion is seen as the nerve regenerates (Fig 68)

Soft tissue changes may take place in a hand following nerve injury such as atrophy of the soft tissue and retardation of nail and hair growth. Sunderland and Ray[3] studied uncomplicated nerve injuries and found the nail growth to be retarded in some cases but not in others. When arterial ligation was superimposed on the nerve injury nail growth was consistently and markedly retarded. These experimental studies corroborate clinical findings that trophic changes are more prominent in combined nerve and vascular injuries

NERVE INJURY PATTERNS

Ulnar Nerve

The area of sensory loss consists of the volar and dorsal aspects of the palm and fingers medial to a line bisecting the ring finger. There are variations in which the line of innervation bisects the fifth, second or index finger. Injuries of the dorsal and volar digital branches produce localized sensory losses

The motor losses depend upon the level of nerve injury. The flexor carpi ulnaris and flexor digitorum profundus to the fourth and fifth fingers are paralyzed if the injury is above or around the elbow. Below this region there is loss of the intrinsic muscles supplied by the nerve. Interosseous palsy will prevent abduction and adduction of the fingers. Since both the lumbricals and interossei will be lost to the fourth and fifth fingers these will be clawed with the interphalangeal joints flexed and the metacarpophalangeal joint extended (Fig 69). The clawing of the fourth and fifth fingers is more severe if the flexor digitorum profundus to these fingers is functioning. Valone[4] suggests that in low ulnar nerve lesions the innervation of the flexor digitorum profundus should be dissected free from the main nerve trunk and crushed to produce a temporary paralysis of this muscle. He feels that if this is done the affect of this muscle on the metacarpophalangeal joint would prevent some of the flexion deformity

guide Its steady progress down the nerve is a rough test of recovery and is known as Tinel s sign However one can never be sure that the nerve fibrils producing the paresthesia will function Other signs of nerve recovery are return of sympathetic tone sensation and motor function Various electrical techniques have been used for testing nerve recovery such as electrodiagnosis and electromyography[2] These are of great prognostic value since

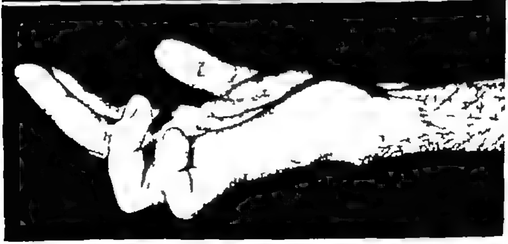


Figure 68 (Top) Herpes-like lesion associated with median nerve recovery

Figure 69 (Bottom) Typical clawing of 4th and 5th fingers in ulnar nerve palsy

Thumb adduction will be gone and can be tested by requesting the patient to grasp a paper between the thumb and second metacarpal On attempting to hold this firmly if the adductor pollicis is not functioning the patient will flex his thumb at the interphalangeal joint in a vain substitute attempt for adduction (Froment s sign) (Fig 70) Pinching of the tip of the thumb against the tip of the index finger will be very weak since this action depends on the first dorsal interosseous and adductor pollicis

Atrophy of the hypothenar eminence and hollows between the metacarpal bones are characteristic The first dorsal interosseous atrophy is very obvious (Fig 71)

Sweating is absent over the area of sensory loss and there is atrophy of the soft tissues of the fifth finger associated with shiny thin skin hair and nail growth changes

Median Nerve

The sensory loss in median nerve palsy consists of anesthesia on the volar aspect of the palm and fingers lateral to a line bisecting the ring finger The dorsum of the distal phalanx of the thumb index middle and radial half of the distal phalanx of the fourth finger similarly are involved The forearm muscles supplied by the nerve will be paralyzed in lesions above and around the elbow Flexion of the third fourth and fifth fingers will be possible due to the pull of ulnar controlled tendons of the flexor digitorum profundus In addition there will be the loss of thumb abduction and opposition Injuries below this will produce only a loss of abduction and opposition of the thumb

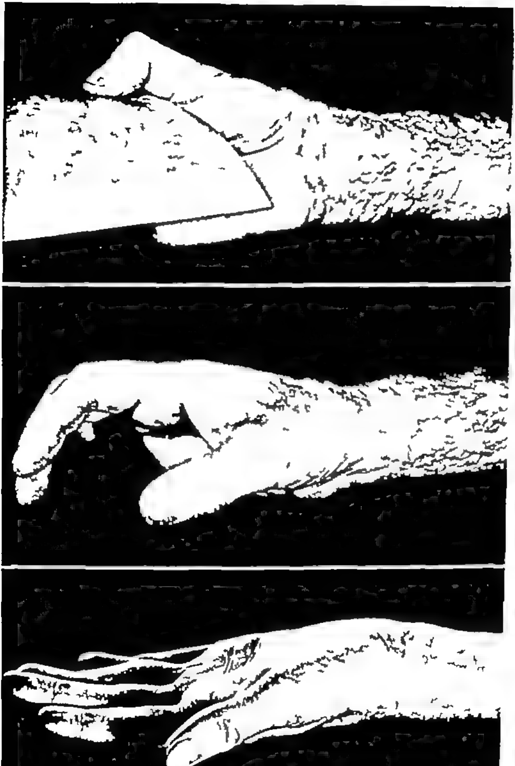
The characteristic appearance is an atrophy of the thenar eminence (Fig 72) Sweating is absent in the sensory loss area and the denervated fingers will show atrophy of soft tissue associated with thin skin hair and nail growth changes

←

Figure 70 (Top) Froment s sign showing flexion of interphalangeal joints as a substitute action for adduction of thumb

Figure 71 (Middle) Atrophy of first dorsal interosseous muscle in ulnar nerve palsy

Figure 72 (Bottom) Atrophy of thenar eminence in median nerve palsy



will be necessary In the case of the ulnar nerve it may be taken from its normal bed behind the medial epicondyle and transplanted anteriorly with care taken to avoid damage to the nerve fibers going to the flexor carpi ulnaris and flexor digitorum profundus An excellent account of this technique is presented by Learmonth[6] The radial nerve may be translocated anterior to the humerus to achieve a similar purpose in the upper arm In rare instances with extensive loss of nerve tissue it may be necessary to shorten bone length to permit anastomosis[7]

There is always the question of how small a nerve should be sutured Digital nerves are sutured as far as the distal interphalangeal joint The motor branches of the ulnar nerve can be sutured in the carpal tunnel The deep branch of the median nerve often is difficult to locate but an effort should be made to find the ends since satisfactory repair is possible Suture of the deep branch of the radial nerve also is attempted since experience during World War II indicates that this may be possible with considerable success Mayer and Mayfield[8] studied fifty-eight cases in which end to-end suture was possible in thirty nine and in 84 per cent of these cases there was partial or full recovery

Although tendon transfers for nerve palsies will be discussed in the chapters on reconstructive surgery it should be mentioned that they may be done as a type of dynamic splinting in cases where nerve recovery may be a long term process

AFTERCARE

Following operation the involved extremity is immobilized in a plaster-of Paris splint for a period of three weeks in a position which gives minimum tension on the suture line. After removal of the cast and sutures physiotherapy is instituted to maintain joint function of all the joints in the involved extremity plus adequate splinting to prevent overstretching of paralyzed nerves Radial nerve injuries require a dynamic cock up splint median nerves a splint to restore opposition to the thumb and maintain the web space between the thumb and index finger ulnar nerves a knuckle bender splint to keep the metacarpophalangeal joints flexed about twenty degrees Multiple nerve injuries will need combination splints

Causalgia which occurs in about 5 per cent of peripheral nerve injuries is most commonly seen after median nerve injuries[5] One reason may be that the median nerve is supplied by the artery of the median nerve which was one of the main blood vessels in the embryologic development of the hand Thus this nerve may be more richly supplied with sympathetic fibers than the ulnar or radial nerve

Combined Median and Ulnar Nerves

The characteristic deformity is flexion of the interphalangeal joints of the fingers with extension or hyperextention of the meta carpophalangeal joints in addition to the deformity produced by the atrophy of the interosseous muscles and loss of the thenar and hypothenar eminences This is the typical clawhand.

Radial Nerve

The sensory loss in the radial nerve injury is on the dorsolateral surface of the hand in the areas not supplied by the median and ulnar nerves Total anesthesia may consist of a small spot on the dorsum of the web space between the thumb and index finger With a complete radial nerve palsy the obvious deformity is the wrist, finger and thumb drop When the deep branch alone is severed there is a characteristic inability to extend the thumb which often may be overlooked This should be watched for particularly in fractures of the head of the radius

METHODS OF REPAIR

The nerve ends are approximated using No 00000 silk sutures which pass through the epineurium of the nerve The suture must not extend into the nerve for fear of damage to nerve fibrils with subsequent poor recovery In old injuries the amputation neuroma is excised back to normal nerve fibrils and the distal end freshened to relatively normal tissue

It is essential to suture the nerve without tension. A simple neurolysis of the involved nerve over a considerable portion of its normal bed often will free sufficient nerve to accomplish this If not joints may be flexed on either side of the nerve repair in order to gain distance If more is needed a nerve translocation

The cause of this condition is varied. A disturbance in the carpal tunnel—such as a fracture, dislocation, or arthritis—may narrow the tunnel so as to produce the syndrome. Rarely acute compression by hemorrhage is a factor. In most cases there appears to be some occupational strain. It is well known that when the wrist is extended the pressure in the carpal tunnel is three times greater than when the wrist is flexed.[13] Also when the wrist is flexed, the edge of the transverse carpal ligament can pinch the median nerve. Thus any action involving extension and flexion of the wrist could conceivably lead to this condition. Increased bulk in the contents of the carpal tunnel also may predispose to the carpal tunnel syndrome. The author recently had a case where at the time of operation the flexor tendons were hyperemic and thickened as if they were the site of a chronic tendinitis. McKee[14] similarly found cases where the flexor tendons were enveloped in an edematous synovial membrane which he felt contributed toward the syndrome. Nissen[15] describes a massive almost acellular hypertrophy of the synovial tendon sheaths that may be found in some cases of otherwise unexplained carpal tunnel compression. Grokoest and Demartini[16] saw two cases with swelling in the flexor tendons due to amyloid disease. Stewart[17] reports a case where there was pain in the wrist and hand due to a bulging underneath the flexor retinaculum of the muscle belly of the palmaris longus which was cured by resecting the involved muscle. Brooks,[18] reports several compressions of the median nerve due to ganglia at the level of the wrist joint.

Treatment is relatively simple and involves incision of the transverse carpal ligament which is exposed through an S-shaped incision across the wrist. The ligament is sectioned along its medial border to minimize the possibility of damage to the motor branches of the median nerve. The carpal ligament is incised throughout its entire length since there have been several cases where a secondary operation was necessary to completely incise the ligament. It is essential that this operation be performed before opponens palsy develops which may be irreversible.

Reports of *tardy ulnar palsy* are increasing in the surgical literature since it was first described by Panas in 1887.[19-21] It is usually due to trauma to the ulnar nerve as it passes behind the medial

Generally sensation returns adequately after a nerve injury and the only problem involved is when the anastomosis line is incorporated in the scar tissue of the wound If this occurs in an area where there is much movement or which is liable to repeated trauma there will be painful sensations produced which may require correction by neurolysis

The larger muscles bellies in the forearm usually return satisfactorily However the intrinsic muscles of the hand are so small that they usually atrophy before they are innervated The best chance for recovery is in a young person where the nerves are cut near the wrist. Therefore the best results are obtained with the radial nerve next best with the median nerve and last with the ulnar nerve since the latter nerve supplies the greater number of intrinsic muscles

COMPRESSION PALSY

The *median nerve* may be compressed in the carpal tunnel producing the carpal tunnel syndrome Usually there is pain over the median nerve distribution and as the disease progresses a definite pattern of hypesthesia or anesthesia will appear over this area Opposition of the thumb may disappear before there are definite sensory changes in the hand Zachary[9] believes that the large fibers (motor) in the nerves are damaged more than the smaller fibers (sensory) in such types of indirect trauma. Percussion of the median nerve at the flexion crease of the wrist may produce paraesthesias along the median nerve[10] As the disease progresses the pain may reach the forearm and even the shoulder The symptoms may be more prominent at night.[11]

The symptoms may be aggravated by temporarily occluding the circulation of the arm above the elbow[12] It appears that the partially injured nerve is more susceptible to ischemia than the normal one therefore the paresthesias and numbness will appear first in the median nerve distribution ratner than in the ulnar nerve The author had a recent case where the symptoms were re produced by occluding the subclavian artery in the neck and agrees that temporary arterial occlusion is a valuable aid in diagnosis

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humeral condyle. The most common causes are old fractures of the elbow and arthritis McGowan[22] studied a series of forty-six cases and in addition to old fractures and osteoarthritis found three cases caused by recurrent dislocation of the ulnar nerve, four presenting bony irregularities in the ulnar groove and three due to soft tissue injury at the site of the ulnar nerve with subsequent compression by scar tissue Three additional cases presented no mechanical abnormality of the elbow joint. The occupation of two of these patients required much hammering and the other was a student who had the habit of sitting for many hours with his elbow pressing against a table. Brooks[18] reports tardy ulnar palsies produced by ganglia at the wrist

Paraesthesias or hypesthesias develop in the ulnar nerve distribution with increasing weakness of the intrinsic muscles Percussion of the nerve in the epicondylar groove will produce paresthesias along its course

When it occurs near the elbow joint, treatment consists of translocation of the ulnar nerve anterior to the epicondyle It is essential to operate before there is definite atrophy of the intrinsic muscles. The importance of this is demonstrated in a series of cases in which all improved as far as sensation was concerned but when there was wasting of interosseous muscle with no voluntary power there was little motor improvement.[22]

It is of interest that leprosy attacks the nerves of the upper extremity at the places where they are most apt to be compressed (the ulnar nerve behind the elbow and the median nerve at the wrist) Dwyer[23] had an unusual case of leprosy of the ulnar nerve at the elbow with relief of symptoms by transplanting the nerve anterior to the epicondyle

The *radial nerve* may be compressed in the healing of a fractured humerus causing a late palsy which may require operation on the fracture site with neurolysis of the nerve The same may occur in fractures of the head of the radius when the deep branch of the radial nerve becomes involved in the fracture site

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CHAPTER 10

BONES AND JOINTS

BONES

As the Hand Surgeon views the various disabilities resulting from trauma he is appalled not so much by those resulting from severe trauma but from the trivial trauma which has been mismanaged by a physician oblivious to universally accepted principles of treatment Probably nowhere is this more evident than in the management of fractures of the fingers and thumb Too often the attending doctor treats these as minor injuries and consequently the fingers and hands become useless tools Before discussing the specific fractures of the phalanges and metacarpus a few general principles will be emphasized

Finger fractures are immobilized in a position of 15 degrees flexion at the metacarpophalangeal and distal interphalangeal joints and 60 degrees at the proximal interphalangeal joint Only the injured finger is immobilized to prevent limitation of motion in the other fingers Watson Jones [1] suggests that even this is not sufficient but that every effort should be made to exercise actively the uninjured fingers through the complete range of motion A finger is not immobilized beyond three weeks if one wishes to prevent limitation of motion of interphalangeal joints During treatment of hand fractures the shoulders are put through a full range of motion daily to prevent limitation of motion of this important joint.

Fractures of the Distal Phalanx

These fractures often are associated with a subungual hematoma which may have to be evacuated to prevent pain and possible secondary infection This is done by turning up a flap of nail using a scalpel Most terminal phalanx fractures heal without

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mal portion of the middle phalanx may give rise to a dorsal angulation due to the pull of the extensor mechanism on the proximal segments

Despite the various deformities all these fractures can be treated in flexion with the involved fingers placed in the position of function When the fractures are not displaced they can be maintained in position by a plaster-of Paris trough If there is overriding and displacement of the fracture ends it will be necessary to use traction to maintain position Pulp traction through the terminal phalanx is adequate providing the traction wire is placed through the periosteum of the distal phalanx (Fig 74)

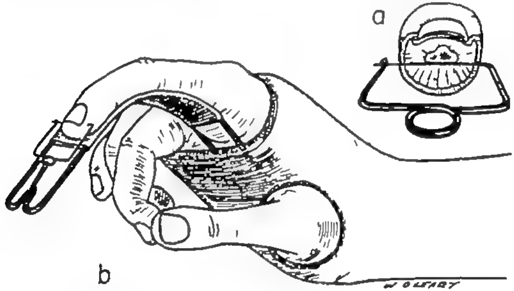

Figure 74 (a) Traction pin placed through periosteum of distal phalanx (b) simple traction apparatus made by incorporating properly bent coat hanger wire in a plaster cast.

Adhesive traction may be used but must be watched carefully for fear of slipping or skin necrosis Quigley * uses a Kirshner wire fashioned to form a fish hook which is inserted into the dorsal aspect of the middle phalanx using a No 6 dental burr by means of which a hole is drilled into the marrow cavity at an angle of 45 degrees distally Active motion is insisted upon throughout the immobilization

A traction apparatus can be made easily by incorporating a wire coat hanger in a plaster gauntlet Adhesive tape or plaster-of Paris slabs are used to prevent the finger from slipping between the wire

difficulty and as a rule can be treated as soft tissue injuries If there is an avulsion of the extensor tendon from the distal phalanx with a resultant baseball finger it is treated as discussed in the tendon section The hyperextension required in treating these injuries however should be modified in cases in which the distal interphalangeal joint is involved either as a chip fracture or as a dislocation Since these usually result in a stiff joint they are immobilized with the distal interphalangeal joint in a slight degree of flexion

Fractures of the Middle and Proximal Phalanges

The insertions of the various muscles and tendons in the fingers will give rise to characteristic deformities when fracture and displacement occurs For instance fractures of the proximal phalanx will usually result in anterior bowing due to a pull of the lumbrical and interosseous muscles flexing the proximal segment and extending the distal joints (Fig 73) Fractures of the distal

Figure 73 Anterior angulation of proximal phalanx fracture site.

portion of the middle phalanx similarly give rise to anterior bowing due to a pull of the flexor digitorum sublimis on the proximal segment. Fractures of the distal phalanx and the proxi

that if a fracture extends into a joint the prognosis is poor since there will be limitation of motion Total immobilization should not last more than three weeks At the end of this period active motion is instituted

In certain phalangeal areas healing is slower than this and it is well to provide some form of protective splint at night to prevent displacement of the fracture site Moberg[7] points out that the narrow portions of the phalanges have the densest bone with a minimal vascular supply Healing time for the narrow portions of the middle phalanx is ten to fourteen weeks for the narrow portion of the proximal phalanx five to seven weeks and for the remaining parts of the phalanges approximately three to five weeks.

In compound fractures where a loss of a portion of the middle or proximal phalanges occur an amputation is often performed. Nemethi[8] suggests that phalangeal recession may be indicated in such areas and presents a series of cases where he established a soft tissue bridge if the artery and nerve (or a reparable nerve) supplying the tissue distal to the wound is present. The gap may be closed by fixing the distal bone fragment to the proximal one with a Kirshner wire The resulting finger is shorter than normal but usually has good motion sensation and cosmetic appearance He maintains that the distal phalanx with its highly specialized sensation and stereognosis its nail and general cosmetic appearance should be salvaged.

Metacarpal Fractures

Fractures of the base seldom present a problem and may be immobilized for three to four weeks in a dorsal splint being sure to keep the fingers and thumb moving

Most fractures of the shaft of the metacarpals are treated by manipulation and immobilized in a plaster gauntlet keeping the fingers and thumb free and moving If the same fragments cannot be held without serious bowing and overriding, open reduction probably is indicated although some can be maintained by traction similar to that used in phalangeal fractures Intramedullary pinning with a Kischner wire offers a satisfactory means of immobilization[9]

struts. When traction is applied it must be remembered that the fingers in the flexed position do not lie parallel to each other but instead point approximately to the scaphoid tubercle (Fig 75)

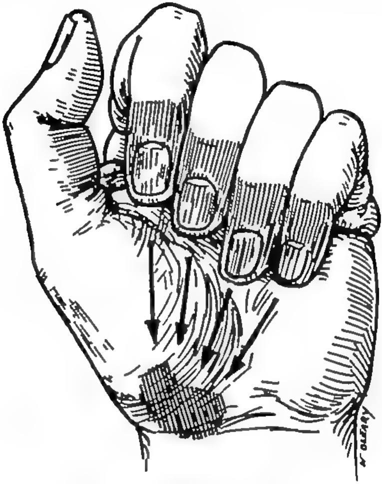

Figure 75 Flexed fingers point to scaphoid.

Intermedullary wiring will produce a satisfactory immobiliza tion allowing for mobility of adjacent joints The distal joint is flexed and a fine Kirshner wire is driven into the bone with a gentle motion using a Steinman hand chuck or some similar driving device After the wire threads the fracture site the excess pin is cut off leaving about one half centimeter projecting which is covered with a sterile cotton or gauze pledget [36]

Frequent x rays are taken of the fracture to be sure that anterior bowing at the fracture site is not taking place since this will inter fere with function of the flexor tendons It is well to remember

Bennett's fracture is an intra-articular fracture dislocation of the thumb at the carpometacarpal joint presenting a triangular fragment on the inner side (Fig 77a) The metacarpal is displaced and slides down along the saddle of the greater multangular This fracture is reduced with traction along the axis of the metacarpal and pressure over the base of the metacarpal (Fig 77b) A plaster gauntlet is applied holding the metacarpal in extension and abduction with traction on the terminal phalanx (Fig 77c) Immobilization and traction is maintained for approximately four weeks followed by immobilization without traction for two or three weeks until union is firm

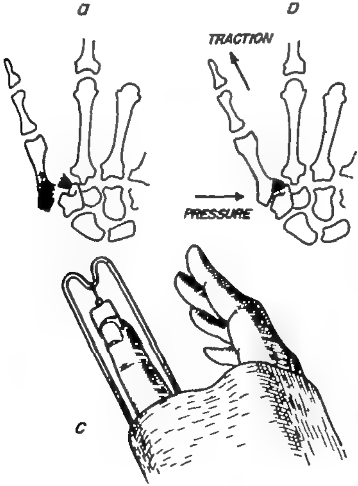

Figure 77 (a) Intra articular fracture-dislocation of base of thumb-meta carpal (Bennett's Fracture) (b) reduction of Bennett's fracture (c) immobilization of this fracture in traction

Fractures of the neck are the most common fractures found in the metacarpal bones If there is only slight displacement of the head the hand may be splinted in this position However any serious displacement of the head requires manipulation This is easily done by pressing the flexed metacarpophalangeal joint backward in the long axis of the phalanx* When the reduction is accomplished the metacarpophalangeal joint may be immobilized by a plaster-of Paris cast placing felt over the extensor surface of the flexed finger and in the space betwen the finger and palm. The fracture is immobilized for three weeks followed by gradual active motion Kirschner wire fixation occasionally may be used to immobilize this fracture

Metacarpal Thumb Fractures

Fractures of the neck shaft and extra-articular base (Fig 76) usually require reduction and immobilization in a plaster gauntlet with the thumb extended and abducted If traction is necessary it may be maintained as previously discussed

Figure 76 Extra-articular fracture of base of thumb metacarpal (Not a Bennett s Fracture)

Kirschner wires also may be of value in treating Bennett's fracture Wagner[10] suggests that the Kirschner wire be driven through the base of the metacarpal into the greater multangular and maintained in this position for four weeks with the thumb in abduction and the wrist dorsiflexed Wiggens *et al*[11] report an excellent series of fourteen cases of Bennett's fracture Under adequate anesthesia the metacarpophalangeal joint is flexed and traction applied along the axis of the metacarpal Direct pressure over the base of the first metacarpal may be necessary to reduce

Figure 78 Fractured sesamoid bone

Figure 79 (Top) Dorsal displacement of Colles fracture.
Figure 80 (Middle) Radial displacement of Colles fracture
Figure 81 (Bottom) Smith's fracture

four to five weeks In older patients it is wise to remove the cast in twelve to fourteen days and re apply a cast in a more neutral position to avoid joint damage Finger elbow and shoulder exer cises are insisted upon during the period of immobilization

Unusual comminution of a Colles fracture will require fixation with skeletal traction applied with a Kirschner wire through the second third fourth and fifth metacarpals after molding of the fracture[15] Other authors advise traction applied through a wire in the base of the thumb with no manipulation of the fracture[16]

About 6 per cent of Colles fractures are associated with fractures of the carpal bones—usually the scaphoid—but rarely the trique trum lunate capitate and greater multangular Colles and scaphoid fractures require opposite positions for reduction and fixation and hence treatment presents a paradox. If the radius fracture is not severe these injuries can be treated as uncomplicated scaphoid fractures. Otherwise they are treated for the Colles fracture for four weeks taking care to immobilize the thumb After this they are immobilized for the scaphoid fracture[17]

Fractures of the *radial styloid process* require immobilization for three to four weeks If there is displacement or irregularity of the joint space they must be reduced before being immobilized

Fractures of the *dorsal lip of the radius* may be easily overlooked and produce a rupture of the extensor pollicis longus tendon as it passes over the sharp irregularity Immobilization for several weeks prevents this

The *reversed Colles' fracture* or Smith s fracture (Fig 81) is reduced by traction and dorsiflexion and immobilized for five weeks

In children falls on the wrist produce *epiphyseal injuries* When the epiphysis is displaced backward from the metaphysis with or without a metaphyseal fragment, no damage is done to the plate and reduction and immobilization such as used for a Colles fracture gives a good result. A crushing injury to the epiphyseal plate will result in arrested growth of the radius The continued growth of the ulna increases the resulting deformity These frac tures may not be seen on initial x ray but in a few months signs are more obvious Subsequent treatment requires resection of the ulna just above the radio-ulnar joint

the fracture After the position is checked with fluoroscopy a medium size Kirschner wire is directed into the posterior aspect of the center of the head and passed through the medullary canal to enter the center of the greater multangular The wire is cut off approximately one centimeter distal to the skin and a small dressing applied with a glove type plaster-of Paris cast including the entire thumb Immobilization is continued for four weeks followed by removal of the wires with active use of the thumb instituted In this series there were no cases of residual instability subluxation non union or loss of joint function

Sesamoid Bone Fracture

A very rare fracture of the hand is that of the sesamoid bones (Fig 78) Several cases are reported wherein a fracture of the sesamoid bone following trauma gives rise to pain and disability Jellinger [12] reports a case following trauma where there was pain swelling and stiffness of the thumb with tenderness over the palmar aspect of the metacarpophalangeal joint. X ray revealed a fracture of one of the sesamoids with a one centimeter distraction between the fragments Reitz,[13] reports several cases where there were injuries to the sesamoid bones giving rise to pain and tenderness which were cured by excision of these bones

Wrist Fractures

Colles' Fracture is the most common one in the wrist joint. Following a fall on the outstretched hand there is a dorsal (Fig 79) and radial (Fig 80) displacement of the distal fragment of the radius resulting in the typical silver fork deformity Disimpaction is performed by traction and not by increasing the fracture deformity since this may increase damage to the median nerve and flexor tendons [14,15] Following this the radial fragment is pushed forward and in a separate maneuver pushed in ulnar deviation *Post reduction x rays should show the articular surface* to be tilted 15 degrees downward and 15 degrees ulnarward Fixation is obtained by a plaster cast applied from just below the elbow to the metacarpal heads extending over the proximal half of the thumb metacarpal Immobilization usually is maintained for

white proximal fragment but which can heal with adequate immobilization

A fracture of the navicular may be associated with a perilunar dislocation of the carpal bones [21,22] Manipulative reduction consists of traction while extending the wrist With the thumb pressed against the capitate the wrist is then flexed Thereafter the hand is treated as with ordinary scaphoid fractures

More complicated dislocations of the lunate in which manipulation is unsuccessful require excision of the lunate bone and proximal fragment of the scaphoid Older patients require wrist arthrodesis since extensive manipulations or operative reductions will be followed by arthritis

JOINTS

Sprains of finger and thumb interphalangeal and metacarpophalangeal joints often have a prolonged period of disability These are treated by immobilization for two or three weeks in a light plaster splint with the joint in a position of slight flexion Following this period of immobilization active motion is instituted. Disability consisting of pain swelling and limitation of motion may take months to disappear

Figure 82. Dislocation of Interphalangeal Joint.

Fractures of the *scaphoid* are the second most common wrist fracture In vigorous male adults it is more common than Colles fractures Obletz [18] believes the strong forearm musculature pre vents hyperextension of the wrist, and hence the shock of the fall on the outstretched hand is transmitted directly to the weak waist of the scaphoid Hyperextension occurs in women and older per sons therefore the force of the fall is passed to the radius result ing in a Colles fracture

The high incidence of non union has been attributed to the blood supply Obletz and Hulbstein [19] find that 67 per cent of 297 scaphoids show arterial foramina along the entire length of the bone In 20 per cent a fracture through the waist may or may not disturb the blood supply to the proximal fragment. In 13 per cent there were no arterial foramina at the waist or proximal to it. Thus fractures of the tubercle (about 10 per cent of all scaphoid fractures) give the best prognosis the waist (75 per cent) the next best and the proximal pole (15 per cent) the poorest.

One of the most common causes of non union is late diagnosis. The fracture line is notoriously slow in appearing on x rays As a consequence after a fall on the outstretched hand snuffbox tenderness and pain on percussing the extended thumb are pre sumptive of a fracture and the wrist should be immobilized for three weeks until new x rays are taken

Another cause of non union is inadequate immobilization The thumb metacarpal is fully abducted and the interphalangeal joint slightly flexed The cast should include this abducted metacarpal since motion of the thumb produces motion in the distal sca phoid [20] When the cast becomes loose it is re applied Immobiliz ation should last nine to ten weeks If x rays and clinical examina tion reveal that healing is not complete further immobilization is continued until healing is complete With this method of treat ment non union is rare

Definite surgical intervention is recessary with malposition of the fracture aseptic necrosis or non union of a small proximal frac ture fragment Excision of the latter after eight weeks of immo bilization may yield good function The aseptic necrosis with its irregular mottled density and partial collapse should not be con fused with temporary avascularity which may appear as a dense

Alldred[25] reports three cases of rupture of the collateral ligament at the base of the thumb associated with swelling at the base of the thumb and pain and weakness of grip When the patient attempted to press the index finger against the thumb the deviation of the thumb from the index finger was seen clinically and by x ray Repair was done by drilling holes through the metacarpal and phalanx and performing a tenodesis with an extensor tendon from the fourth toe followed by plaster immobilization for four weeks

Figure 84. Irreducible dislocation of metacarpophalangeal joint of thumb.

Dislocations of *interphalangeal* and *metacarpophalangeal* joints usually are due to hyperextension trauma with the phalanx displaced backward (Figs 82 and 83) Reduction is accomplished by traction with the joint immobilized for three to four weeks in a plaster-of Paris cast in a position of function.

Burman[26] reports an irreducible hyperextension dislocation of the metacarpophalangeal joint of the index finger where the interposition of flexor tendons between the bones prevents closed reduction and necessitates open reduction

Dislocation of the *metacarpophalangeal joint of the thumb* is

Tears of the capsules of the finger joints may give rise to various deformities Portis [23] presents a case of an unusual avulsion of the palmar portion of the proximal interphalangeal joint capsule As a consequence of this injury there is herniation of the head of the proximal phalanx through the aperture in the capsule. The finger cannot be extended fully in a normal manner On attempted extension the proximal interphalangeal joint subluxates into hyperextension and the distal joint falls into partial flexion He treated several cases by repairing the anterior capsule with interrupted silk sutures and subsequent immobilization with the finger in a position of function

Alldred,[24] presents an interesting report of an injury where the patient felt *a painful snap on the radial side of the metacarpophal* angeal joint of the index finger This resulted in a deformity with the metacarpophalangeal joint held at 40 degrees flexion At operation a tear was found in the joint capsule the proximal part of which had retracted and rolled up into a tight band which was caught around the metacarpal head The defect in the capsule was closed and the finger immobilized for three weeks After this there was a good return of function

Figure 85 Dislocation of metacarpophalangeal joint

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Dislocation of the *metacarpophalangeal joint of the thumb* is

one of the most common dislocations of the hand (Fig 84) The phalanx is displaced backward and the head of the metacarpal is driven through a split in the joint capsule which closes around the bone The tendon of the flexor pollicis longus and the sesamoids which are constant in this region further aid in locking the dislocation This usually has to be repaired by an open reduction with an incision in the metacarpophalangeal crease of the thumb (Fig 85) Through this incision the volar plate of the joint capsule is reached and divided separating the two sesamoids and permitting the release of the head of the metacarpal

Dislocation of the *lunate bone* usually results from a fall on the dorsiflexed hand The lunate bone is squeezed between the radius and capitate bones into the carpal tunnel producing compression of the flexor tendons of the finger and median nerve Clinically

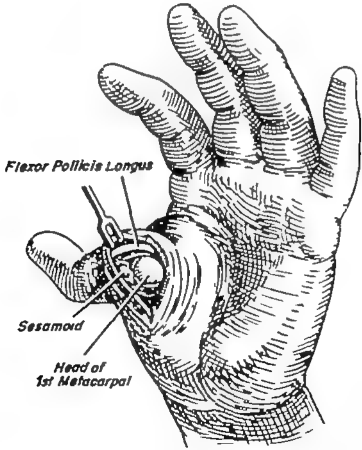

Figure 83 Incision for open reduction of dislocated metacarpophalangeal joint of thumb

there is limitation of motion of the fingers with median nerve palsy and swelling and thickening of the volar surface of the wrist X rays will reveal the diagnosis If seen early they may be reduced by applying traction to the fingers and thumb with pressure applied to the volar surface of the dislocated bone After manipulation the wrist is immobilized in 45 degrees flexion for a week to ten days following which a new cast is applied with the wrist in neutral position for another two weeks If the closed method fails the lunate may be reduced through an incision over the front of the wrist between the flexor carpi radialis on one side and the flexor tendons and median nerve on the other Following this procedure the wrist is placed in flexion and incorporated in a plaster-of Paris cast. If old dislocations produce symptoms complete excision of the lunate bone may be necessary Hambly[27] suggests that there is a strong case for excision of the lunate immediately after injury and quotes one surgeon who excised a semilunar with the result that twenty years later the patient had no apparent disability of the wrist joint.

Similar dislocations may occur in the *carpal scaphoid*[28] This usually is caused by injury with the hand gripping something in ulnar deviation and dorsal extension of the wrist It can be corrected by applying traction with pressure over the proximal pole of the bone The wrist is immobilized in moderate dorsi flexion and radial deviation

There are many combinations of bones involved in numerous dislocations of the *wrist* Generally when these are fresh they can be reduced by traction and manipulation When old open reduction is necessary to restore normal anatomy Complications include degenerative arthritis and aseptic necrosis of the carpal bones particularly the scaphoid The peri lunar dislocation is the most common and may be confused with dislocations of the lunate bone However the lunate retains its normal relationship with the radius and the remaining carpal bones are displaced dorsally and radially Associated with this there may be fractures of the scaphoid and the radial and ulnar styloid processes Fresh dislocations are reduced by traction and manipulation after which they are immobilized in plaster from the knuckles to the elbow with the wrist flexed 30 degrees Older dislocations need open reduction

A somewhat neglected dislocation is that of the *carpometacarpal joint* Since little motion is attributed to these joints the resultant disability from such dislocations usually is overlooked. It should be emphasized that the fifth carpo-metacarpal joint is more like a saddle joint and closely resembles the first carpo-metacarpal joint. Its motions are essential for cupping of the palm in grasping an object and for a firm grip An arthritis developing here may interfere with the mobility of the hand and weakens the grip Ker [29] reports a dislocation of the fifth carpo-metacarpal joint that could not be reduced and in which an open reduction was necessary with maintenance of the reduction by suture Waugh and Yancey [30] similarly report on such dislocations and point out that occasionally Kirschner wires will be necessary to hold them in place

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CHAPTER 11

SPECIAL INJURIES

Apart from the usual trauma afflicting the hand there are certain injuries which because of rarity peculiar occurrence or bizarre tissue response require separate explanation

THERMAL BURNS

Burns markedly limit hand mobility by destroying skin elasticity and underlying tendons and joints This is most marked on the dorsum where skin stretching is most needed and where the joints lie immediately beneath the skin surface Additional restricting fibrosis is produced by secondary infection edema and immobility

Initial treatment consists of minimal debridement of loose skin shreds using sterile technique A thin layer of vasoline gauze is placed over the burn and between all the fingers to prevent their adherence to one another The fingers are spread apart with all the joints placed in slight flexion the thumb held in a position of abduction and opposition and the wrist dorsiflexed to 15 degrees The remainder of the dressing is made up of gauze or sterile mechanics waste and the entire hand wrapped with an Ace bandage so that a firm but not tight dressing will be maintained After five to seven days the dressing may be changed daily the hand soaked in half strength Dakin s solution and motion permitted

The burn wound is closed as soon as possible with split thickness skin grafts approximately 12/1000 inch in thickness In order to hasten the time for grafting, the burn slough is removed surgically or with chemical debridement using various substances such as pyruvic acid phosphoric-acid gel and proteinase [1-3] However the slough is more difficult to separate chemically when it involves the palmar fascia or the fascia of the back of the hand and surgical excision is more satisfactory

Motion is started in the fingers as soon as possible after grafting procedures This may be aided by dynamic splinting and physiotherapy

Because of the tendency to protect the face in exposure to fire burns frequently occur on the *dorsum of the hand* Since the elasticity of the dorsal skin is so essential to full flexion of the hand even minor burns limit mobility [4,6] When the burn does not involve the underlying tendons the granulating area or thin atrophic scar is excised completely in a bloodless field with care taken to avoid the underlying veins and nerves Excision is so planned that the resultant scar will not cross the flexion crease at the wrist or finger joints in a straight line [7,8] A split thickness graft is tailored to fit the defect and sutured in place The web space of the fingers are prone to develop adduction contractures therefore skin grafts should cover the web space completely down to the volar surface taking care that the digital nerves in this area are not damaged

When dorsal burns are deep and underlying tendons or bones are involved a split thickness graft is not adequate and a pedicle flap of skin and subcutaneous tissue must be used followed by subsequent reconstructive procedures on the tendons and joints Even when the dorsum has been properly skin grafted contracture of joints and connective tissue in the hand may remain which must be corrected by proper dynamic splinting and physiotherapy The most common defect is the flexion deformity of the wrist associated with extension or even hyperextension of the metacarpophalangeal joints and flexion of the interphalangeal joints A dynamic splint must be applied which will flex the metacarpophalangeal joints and extend the proximal interphalangeal joints If it is not possible to do this by dynamic splinting capsulotomy will be necessary At times the hyperextension of the metacarpophalangeal joints may be so severe that dislocation of the phalanges on the metacarpals occur necessitating resection of the metacarpophalangeal joints [9]

Burns on the *volar surface of the hand* usually are produced by contact with a hot object If the palmar fascia is involved the natural sloughing of burned tissue is delayed and surgical excision is necessary When tendon sheaths are preserved a deep split

thickness graft is satisfactory but if the tendon sheaths are involved a pedicle flap will be necessary to permit subsequent reconstructive tendon surgery

Burns on the *fingers* may be adequately covered with split thickness skin grafts. As a rule, if the burn destroys underlying tendons or joints reconstructive procedures are useless

Skin grafting often is needed for other reasons than improving hand mobility Hypertrophic scars deeply pigmented areas, and thin atrophic scars which ulcerate easily on use need excision In addition there is the potential danger of cancer developing in such scars [10]

It is obvious that the sooner a burn wound is healed the less chance there is for subsequent contractures There is an increasing tendency to excise burns at the time of injury with immediate split-thickness skin grafting Ross [11] found that the average healing time in a series of such burns was twenty five days compared to forty where the grafting was delayed until the third week. However Williams [12] states that the same percentage of hands developed contractures which were treated by primary grafting on the tenth day as compared to children who were treated subsequently by grafting He believes that the reason is that proper splinting of the hand was not carried on after the skin grafting

Further discussion of the reconstructive procedures necessary to restore mobility will be found in Part V

RADIATION BURNS

Exposure of skin to radiation may result in dire consequences. Persons involved in administering radiation therapy are most often affected Mason [13] reviewed sixty-eight patients with irradiation injuries of the hand and found that 58 per cent occurred in physicians dentists roentgen or radium therapists and radiological technicians The majority of the remaining cases were patients treated for benign lesions such as acne plantar warts port wine stains epidermophytosis etc Particularly tragic are those burns resulting from the use of x ray for removal of excess hair [14] Occasionally prolonged fluoroscopic examinations will produce unfortunate burns.[15]

In addition to radiodermatitis, x ray may damage growing epiphyses Daland[16] reports the case of a young girl who was treated with radium for a hemangioma at the base of the right thumb Radiation dermatitis developed at the site and the thumb grew to only one-half the length of its normal size

Acute burns usually are the result of a single large dose and are most commonly seen in the hands of doctors or patients after fluoroscopy There is edema and erythema with deep boring pain and vesiculation and desquamation may occur as in an ordinary burn In severe cases the skin may turn white slough and become an indolent ulcer

In a case report by Hempelmann[17] the hands became swollen within thirty minutes after massive exposure corresponding to the equivalent of from 20 000 to 40 000 roentgen units of an 80-kilovolt x ray machine. The right hand blistered thirty-six hours after exposure and destruction of the skin continued on the right hand and forearm During the second week, just prior to the patient s death there was dry gangrene of the fingers of the right hand and left thumb

Treatment of acute burns consists of sedation for control of pain and a bland ointment such as cold cream or lanolin to seal the burn from the air A loose soft dressing plus immobilization of the hand in the position of function are further adjuncts.

Chronic radiodermatitis is manifested by atrophy telangiectasis and keratosis of the skin A study of the histopathology of these changes revealed fibrosis atrophy of the skin telangiectasis and obliterating endarteritis[18 19] Daland[16] reports the loss of subcutaneous fat in the radiated area

Carcinoma occurring in radiodermatitis is more frequent after prolonged minimal exposure to the alpha and beta rays and usually is seen with high voltage radiation The incidence of carcinoma varies from 20 to 32 per cent[19-22] It is usually a squamous cell type but a basal cell type may occur Radiodermatitis makes the skin more sensitive to other chemical mechanical bacteriological and x ray stimuli The effect of sunlight may be very striking[18]

Treatment consists of excision of the area with closure by split thickness skin graft or if necessary by flap grafts

thickness graft is satisfactory but if the tendon sheaths are involved a pedicle flap will be necessary to permit subsequent reconstructive tendon surgery

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then ejected into the finger or hand in varying quantities and pressures (Fig 86) It spreads diffusely throughout the tissue of the finger and hand even going into the wrist and forearm There is pain and swelling in the involved area due to the pressure of the mass chemical irritation of the grease and secondary infection

Treatment in the acute phase will depend upon whether the grease is localized or widely dispersed throughout the hand X rays will prove this point[23,24] When the grease is seen on x ray as a localized mass an incision over the grease permits it to slowly extrude from the tissues. Fingers white from ischemia become hyperemic. If the x ray demonstrates a wide dispersion of grease conservative treatment is indicated consisting of chemotherapy to prevent secondary infection and sedation for pain Surgery should be limited to cautious removal of sloughing tissue and/or incision of fluctuant areas when abscesses develop Hot soaks should not be used since they will increase the tissue demands for blood in the presence of a finger which is ischemic After the acute phase is past the involved tissues react to the retained grease in various ways Some may be extruded to the exterior if it is close to the surface (Fig 87) However most of the grease is encapsulated in chronic inflammatory tissue and either remains permanently in the injured area or is slowly removed by phagocytosis The encapsulated grease may not remain inert but may stimulate oleomas which should be excised[23]

RING INJURIES

If the ring on a finger gets caught on a moving part, it may completely or partially denude a finger of its skin Another mechanism for this injury is when someone loses his balance on attempting to reach a high object and falls catching the ring on a hook or other projection thereby throwing his entire weight on the ring Such injuries usually require amputation since the digital nerves and blood vessels may be severed. Kandera[25] reports ten such denuding ring injuries in two of which the finger was saved by applying an abdominal flap

The chronic pressure of the sharp edge of a ring against a phalanx may result in its eroding through the finger and bone

GREASE GUN INJURIES

The injection of grease or oil under pressure produces numerous hand injuries Certain grease guns have a needle like ejector which can inject grease under high pressures (1 000 to 7 000 pounds) The operator accidently touches or comes very close to the end of the ejector while the trigger of the gun is tripped Grease is

Figure 86. (Top) Grease gun injury to ring finger seen several hours after occurrence

Figure 87 (Bottom) Grease gun injury weeks after occurrence showing pits through which some of the grease extruded.

It is of interest that the x rays of the hand show that the air filled the mid palmar space but did not go past the intermediate palmar septum However it did communicate with the web spaces of the fingers along the lumbrical muscles

PORCELAIN FAUCET INJURIES

The porcelain faucet handle particularly the straight bar type is a lethal weapon Attempting to force this open or closed may result in the handle breaking into sharp pointed edges Since the force usually is exerted along the palm the handle penetrates the palm and produces severe injury Seventy four injuries of this type were reported in which there was nerve or tendon damage in all but one [22] Any tendon of the hand may be involved but since the pressure is usually along the thenar flexion crease the tendons of the thumb index, and long fingers are most commonly involved The median nerve was injured in sixty-cases and the ulnar nerve in three

WRINGER ARM INJURIES

When an arm is caught between the rollers of a power driven washing machine wringer or some other type of mechanical roller the involved extremity is contused or crushed depending upon the type of wringer The area becomes swollen and ecchymotic due to damage of underlying capillaries If edema is not prevented severe ischemic changes may occur in the hand and forearm Devitalized skin may slough leaving granulating wounds which often are seen in the most proximal portion of the arm where it is squeezed against the rollers More severe crushing may produce tendon and joint injury X rays rarely demonstrate fractures Several authors have reviewed their experiences with this lesion [23 25]

Basic treatment consists of a sterile pressure dressing applied with an elastic bandage from the fingertips to the axilla with the hand placed in the position of function To prevent secondary infection chemotherapy is recommended The wound is examined carefully daily for the first few days to see if there are any accumulation of fluid or blood in the extremity which may require evac

Such a case was reported where two-fifths of the circumference of a gold wedding ring lay within a tunnel passing through the proximal phalanx of the left ring finger [27]

AEROSOL BOMB INJURIES

Metzler [28] reports the failure of an aerosol bomb resulting in a severe hand injury When the needle valve was opened it was blown out allowing the mixture of pyrethrum DDT and Freon to escape The operator placed his hand over the opening in an attempt to stop the flow and rushed the bomb out of the dwelling When he disposed of the bomb his hand was frozen into the shape in which it had been cupped over it. Examination demonstrated injuries equivalent to a third-degree burn.

BERYLLIUM GRANULOMAS

Beryllium produces various skin lesions such as dermatitis, cutaneous ulcers and subcutaneous granulomas Flynn [29] reviewed this subject and reported two cases of subcutaneous beryllium granulomas of the hand in persons who had been cut with fluorescent light bulbs The tendons of the fingers had to be excised with subsequent skin and tendon grafting The granulomas consisted of fibroblastic tissue with lymphocytes and multinuclear giant cells Although beryllium has not been used in making fluorescent light bulbs since 1949 there are still many in stock and caution should be exercised in disposing of the burned-out beryllium fluorescent lamps Talbert and Caylor [30] report the case of a beryllium granuloma appearing in the web of the left thumb the skin of which was covered with fluorescent powder following laceration with broken neon tubing

COMPRESSED AIR INJURIES

Desmond,[31] reports the case of a metal miller who directed the nozzle of the air compressor pump to his hand while attempting to remove a piece of metal shaving from his finger The hand instantaneously became swollen and painful The emphysema was confined mainly to the palmar space and its lumbrical extensions With conservative therapy such hands recover complete function

of tissue Two such injuries have been reported the more severe producing destruction of extensor tendons and metacarpal bones as well as skin [40] Treatment consists of removal of the solidified plastic leaving the wounds open Subsequent reconstructive surgery is performed as indicated

GUNSHOT WOUNDS

The physical factors involved in gunshot wounds has been well studied [41,42] A compressed pressure wave precedes the bullet and moves out rapidly in all directions from the point of impact. In the wake of the missile a cavity forms which separates from the missile and appears to expand and contract several times Thus in addition to the injury of the missile there is pulping and explosive damage to the tissue due to this compression wave

The wound of entry may be small and round and the wound of exit large and expansive The initial treatment consists of thorough cleansing and debridement The wound is left open and placed in a compression dressing as soon as possible In about seven or eight days if the wound stays clean it can be converted into a closed one by the suture of a skin flap or a split thickness graft. At a later date reconstructive surgery can be performed as necessary Various authors who report on this type of injury find that these principles give satisfactory results [43-45]

HYDROFLUORIC ACID BURNS

Hydrofluoric acid which has many uses in industry causes a deep slow-healing painful burn (Fig 88) In severe cases there is noticeable destruction of tissue which may continue over a period of several days to weeks. Hydrofluoric acid has an extraordinary penetrative ability It has been demonstrated that the intact hydrogen fluoride molecule is capable of penetrating intact epidermis

Such burns are immediately washed with a warm solution of sodium bicarbonate followed by soaking of the part in alcohol As soon thereafter as possible under general or regional anesthesia the soft tissues underneath the skin are injected with 10 per cent calcium gluconate This is done so that the fluorides in the tissues will be precipitated as insoluble calcium fluoride [46]

uation As the skin is lost and sloughs away skin grafting will be necessary If there are tendon or joint deformities tendon grafting and capsulotomy will be necessary and will be further discussed in the reconstructive section

THE CORN PICKER HAND

The mechanical cornpicker is capable of producing extensive injuries to the hand which embrace the entire field of hand trauma. Because of their extensive nature, they have been made the object of special study [36 37]

WELDER'S INJURIES

During the process of spot welding a spray of red hot metallic particles occur which may produce severe injuries if they penetrate the eye Twelve cases have ben reported in which these sparks penetrated the hand giving rise to minute wounds with subsequent secondary infection and tiny foreign body granulomas [38] Early surgical treatment is indicated and a careful excision of dead tissue should be done with extraction of the metallic particles and immediate suture.

INDELIBLE PENCIL WOUNDS

Indelible pencils may contain aniline dyes which cause necrosis of the tissue if they accidentally penetrate the skin Such wounds may persist as a chronic discharging sinus or indolent ulcer When seen early the treatment is surgery consisting of excision of the entire discolored area with the resulting wound left open Ferrier [39] reports an injury of this type treated in this fashion with an excellent result

PLASTIC INJURIES

The increased use of plastic material in industry has produced a new injury This material is driven under pressure and ejected through outlets into various molds The hand accidentally may be injured similar to grease gun injury and the foreign material introduced directly into the hand where it immediately solidifies This produces intense pain swelling and numbness in the involved area and the intense temperature will give rise to severe destruction

that some other factor is necessary to explain a hematoma which stimulates such a fibrous tissue reaction

To prevent hard edema it appears logical to evacuate all traumatic hematomas on the dorsum of the hand as soon as possible Once the fibrosis takes place this tissue should be completely removed since recurrences may occur Cortisone may be useful once the fibrous tissue has been excised

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HARD EDEMA FOLLOWING TRAUMA TO THE DORSUM OF THE HAND

This entity first described by Secretan[47] is a curious clinical entity that is caused by a blow to the back of the hand which is followed by persistent swelling In time the edema becomes hard and one can feel the firm fixed mass on the dorsum. Fixation of underlying extensor tendons may prevent full flexion of the wrist and fingers When the mass is surgically excised fibrosis with occasional cyst formation is found attached to the extensor tendons. Accordingly this disease is called Peritendinous Fibrosis[48]

It appears to be the consensus of modern authors that this hard edema is due to a reaction to hematoma. Excision of such a mass revealed that it contained macrophages composed of hemosiderin[49] Exploration of two cases demonstrated evidence of old and recent hemorrhage with fibrous tissue proliferation and organization in the hemorrhagic area[50] However one must agree with McKenzie[51]

Figure 88 Hydrofluoric acid burn of right hand.

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PART IV

OTHER DISEASES

CHAPTER 12

GENERAL DISEASES AND OCCUPATIONAL STIGMATA

Apart from its local diseases the hand is a mirror of general medical conditions and occupational strains Careful examination may reveal significant clues for the diagnosis of many other diseases.

MEDICAL DISEASES

Dermatologic disorders may affect the hand especially vitiligo tinea eczema and scabies. Cohen and Hopkins[1] report a case of epidermolysis bullosa in which there was so much destruction of the skin of the hand and fingers that the entire hand was encased in a mitt of smooth scar tissue A similar case was reported where complete destruction of both hands developed.[2] A further discussion of the various skin lesions which appear on the hand will not be attempted but it is to be emphasized that they are important since Downing[3] estimates that 80 per cent of a dermatologist s practice consists of the diagnosis and treatment of skin disorders of the hand. The majority are due to occupational or recreational pursuits

It is beyond the realm of this book to discuss *cyanosis* which the hand and particularly the nail bed demonstrates so readily A peculiar red discoloration of the skin of the distal end of the extremities called *acroerythrosis* may be found in tuberculosis Banyai and Hersh[4] found it to be present in 23 per cent of moderately advanced 40 per cent of far advanced and approximately 50 per cent of preterminal stages This often was associated with palmar erythema These authors feel that the latter condition may have been due to poor liver function which often is found in advanced tuberculosis

Heart disease may exhibit itself in the hands by signs other

than of the mucous membranes or conjunctiva Wintrobe [12] states that when the skin creases across the palm lose their reddish pink color the hemoglobin level may be judged as being below seven grams per 100 milliliters In a study of 1500 patients only twenty failed to show this correlation [13]

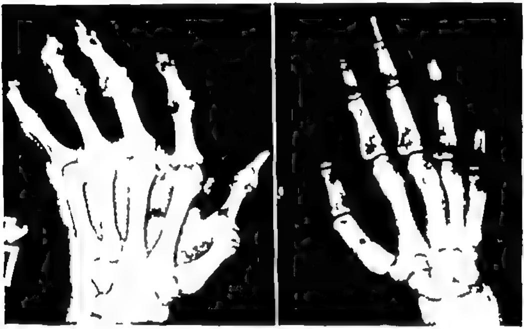

Fig 89 Fig 90

Figure 89 Gout. Extensive joint destruction with punched out areas of radiolucency in subchondral bones of the phalanges.

Figure 90 Hypertrophic pulmonary osteoarthropathy involving meta carpals and phalanges.

Congenital lesions of the hand should make one suspicious of other congenital and associated diseases Arachnodactyly (described by Marfan in 1896) may be associated with many severe abnormal ities such as patent foramen ovale mitral and aortic valvular dis ease myocarditis and dissecting aortic aneurysm Whittaker and Sheehan [14] report two cases of a dissecting aortic aneurysm as an isolated lesion in members of a family showing other features of Marfan s syndrome Aortic hypoplasia associated with Marfan s syndrome is described by Whitfield *et al* [15] Small paraungual fibromas have been observed in tuberous sclerosis of the brain [16]

The hand has not been neglected in *neuro psychiatric diagnosis*

than cyanosis or clubbing Bacterial endocarditis may demonstrate a small tender nodule in the finger pad (Osler node) which lasts only a few days a small erythematous patch in the palm (Janeway lesion) or a splinter hemorrhage beneath a nail[5] Myocardial infarction may be complicated by the shoulder hand syndrome in which there is a painful disability of the shoulder with general swelling of the hand followed gradually by a flexion deformity of the fingers[6] The relationship of this syndrome to Dupuytren s contracture will be discussed in the chapter devoted to this disease. Shapiro *et al*[7] describe vesicles which appear over the hand in relation to an acute posterior myocardial infarction The vesicles progressed to ulceration with healing in approximately two weeks They believe these were caused by impulses from the infarcted heart mediated antidromically through the sensory nerves. A subcutaneous nodule of acute rheumatic fever may appear over the knuckles Circulatory dynamics may be seen in the hand in the capillary pulsations of aortic insufficiency and the cold cadaveric hand of shock.[8]

Endocrine disorders may produce profound changes in the hand such as the warm moist hands of the hyperthyroid, the rough dry cold hands of the cretin the broad coarse hands of the acromegalic, the hyperpigmentation of Addison s disease and the carpal spasm of tetany

Liver disease may show palmar erythema and spider angiomas Flat fingernails and a ground-glass-like opacity of almost the entire nail bed which give the appearance of white nails, have been found in connection with cirrhosis[9-10]

Metabolic diseases may be seen in the hand. Gouty tophaceous deposits appear in the hand and fingers and require surgical excision because of cosmetic deformity pain interference with joint and tendon motion and persistent discharging sinuses[11] X ray shows well defined punched out areas in the subchondral bone of the phalanges More severe stages of the disease exhibit thinning of the joint space and extensive joint destruction (Fig 89) Other metabolic stigmata are the xanthomas

Nutritional disorders seen in the hand are the dorsal erythema of Vitamin B deficiency and the subungual bleeding of scurvy Anemia may be more accurately judged by the pallor of the hand

than of the mucous membranes or conjunctiva. Wintrobe [12] states that when the skin creases across the palm lose their reddish pink color the hemoglobin level may be judged as being below seven grams per 100 milliliters. In a study of 1500 patients only twenty failed to show this correlation.[13]

Fig. 89

Fig. 90

Figure 89. Gout. Extensive joint destruction with punched out areas of radiolucency in subchondral bones of the phalanges.

Figure 90. Hypertrophic pulmonary osteoarthropathy involving metacarpals and phalanges.

Congenital lesions of the hand should make one suspicious of other congenital and associated diseases. Arachnodactyly (described by Marfan in 1896) may be associated with many severe abnormalities such as patent foramen ovale, mitral and aortic valvular disease, myocarditis and dissecting aortic aneurysm. Whittaker and Sheehan [14] report two cases of a dissecting aortic aneurysm as an isolated lesion in members of a family showing other features of Marfan's syndrome. Aortic hypoplasia associated with Marfan's syndrome is described by Whitfield *et al.*[15] Small paraungual fibromas have been observed in tuberous sclerosis of the brain.[16]

The hand has not been neglected in *neuro-psychiatric diagnosis*

Excessive palmar sweating with or without tremor has been well known in neurocirculatory asthenia. The activity of the hands may manifest underlying neurologic psychiatric disorders such as the restless hands of the neurotic, the calm warm hand of the well adjusted personality the pill rolling movements of Parkinson s disease the aimless motions of the athetotic patient, etc. Schachter [17] believes that the infantile fifth finger (symptom of Du Bois) is more frequent among problem than controlled children Palmar dermatoglyphics may be helpful in diagnosing mongolism at an early age.[18] An entire book has been written on the relation of the hand to mental and psychiatric disorders.[19]

Fay [20] reviewed the motions of the thumb as a clinical aid in diagnostic screening of paralysis Cortical lesions which give rise to a cortical spastic paralysis will demonstrate a thumb which remains flexed at the tip and drawn into the palm. Basal ganglion lesions will give rise to the midbrain thumb where the patient cannot rapidly and repeatedly touch the tip of the thumb to the tip of the index or middle finger The movement is slow stiff and delayed. When the spinal cord is directly involved such an atrophy or weakness of the intrinsic muscles may occur as to permit the tip of the thumb to be placed completely back of the knuckles of the index finger (cord thumb) Isolated paralysis of the median and ulnar nerve can be easily differentiated in thumb movements and paralysis of the brachial plexus will give rise to a flaccid type of paralysis where the thumb cannot touch the tip of the fingers be held to the side of the index finger or be cocked backward in extension

Clubbing of fingers is commonly associated with cardiopulmonary disease There is swelling of the ends of the fingers and the nailbed phalanx angle is increased The nailbed is thickened spongy and curved around the sides and tip of the fingers. It usually is bilateral but may be unilateral and even unidigital.

As the disease progresses there develops an expansion of the periosteum of the shafts of the phalanges (hypertrophic osteoarthropathy) (Fig 90) The same process occurs in the periosteum of the more proximal long bones and new bone is laid down along the shafts The medullary cavity does not become narrowed.

The basic pathology was well studied by Lovell [21] who found

that increased fibrous tissue in the nailbed is the earliest and most constant change. This connective tissue increase appears to be due to increased blood flow in excess of local physiological needs and its location in the distal finger segment is attributed to the predominence of AV anastomoses. Mendlowitz[22] first demonstrated that clubbing was associated with an increased blood flow in the affected fingers and this was corroborated by Wilson[23] and Charr and Swenson.[4]

The increase in blood flow to an extremity may be a primary disturbance in aneurysms and AV fistulas explaining the association of club fingers with these diseases. It also explains the clubbing seen in congenital heart disease when there is a right-to-left shunt and in pulmonary AV fistulas where there is a similar passage of blood from the right to the left side. Although aneurysms of an extremity give rise to ipsilateral clubbing, one wonders why there is an increased blood flow distal to the aneurysm. Cross and Wilson[25] find this possible if a valvular mechanism is present in the afferent vessel so that the elastic recoil of the sac forces the blood distally. Thus, fusiform aneurysms are not associated with clubbing whereas the syphilitic type, which is spherical and saccular and more likely to have a valvular angulation at the point of entry to the artery, is more apt to produce the clubbing. The increased circulation in thyrotoxicosis may explain its occasional presence in this disease.[26] Persistent dilatation of the blood vessels in pleuropulmonary infections may produce increased peripheral systemic blood flow and account for the clubbing commonly seen in these diseases.[23]

The increased blood flow may be a secondary disturbance to anoxia explaining the clubbing in cyanosis, methemoglobinemia, sulphemoglobinemia and in chronic infections of the lung (tuberculosis, bronchiectasis, empyema, abscess). However it is also found in ulcerative colitis and various neoplasms.[27,28] Mauer[29,30] makes the interesting observation that when the sedimentation rate is rapid due to the increased level of serum globulins, the red cells tend to form rouleaux. As a consequence the diffusion surface per unit of hemoglobin is reduced and the tissues remain relatively anoxic. This may explain the incidence of clubbing of the fingers in some of these diseases.

BONES

Numerous general bone and joint diseases may be seen in the hand a few of which will be briefly discussed or defined

Developmental

Osteogenesis imperfecta is characterized by deficient matrix formation abnormal fragility of bones and blue sclera X rays will show osteoporosis thinning of the cortex diminution of the shaft in the middle with some flaring toward the metaphysis and multiple fractures *Osteopetrosis* or marble bones shows an increase in the density and thickness of the bones The phalanges may show only a dense transverse band in the metaphysis adjacent to the epiphyseal line

Fibrous dysplasia of bone is characterized by regressive changes thinning of the cortex and replacement of the marrow by fibrous tissue containing abnormal fibrous bony spicules. When associated with precocious puberty and pigmentation of skin it is known as *Albright s syndrome* X rays show central cyst like areas of translucency which may contain coarse trabeculae The bone is broad or expanded The cortex is thinned and there is a trabeculated and cystic appearance The cystic spaces are filled with proliferating connective tissue of immature spindle cells.

Multiple enchondromatosis is a developmental disease characterized by multiple cartilagenous tumors in the long bones. It often is known as Ollier s disease When associated with multiple soft tissue hemangiomas it is known as *Maffucci s syndrome* *Multiple cartilaginous exostoses* may affect the metacarpals.

Osteopoikilosis is an uncommon affliction in which multiple islands of compact cancellous osseous tissue are found It may occur in the carpal and metacarpal bones and to a lessor degree in the phalanges (Fig 91) *Stippled epiphyses* is a congenital defect of chondroplasia in which multiple diffuse calcifications occur in the ossification centers of the bones. It may be seen in the carpus and must be differentiated from a similar condition seen in hypothyroidism *Osteopathia striata* (Voorhoeve s disease) is characterized by longitudinal striations of all the bones but the skull and clavicle The long bones of the hand may be involved

Melorheostosis demonstrates a bizarre irregular flowing hyper plastic deposit upon and in the bones of an extremity Campbell [31] reports a case of a twenty six year old miner who complained of pain and stiffness which had been present for a year in the right thumb and for eight years in the right shoulder X ray revealed a thickened right thumb with marked limitation of motion of the metacarpophalangeal and interphalangeal joints. They also revealed the typical "candle grease flow" of melorheostosis evident in the lower end of the radius in the carpus on the radial side and in all the bones of the thumb There was evidence of disease in the upper half of the humerus and in the coracoid process of the scapula

Fig 91

Fig 92

Figure 91 Osteopoikilosis.

Figure 92. Delayed epiphyseal closure leading to elongated digits.

Chondro-dystrophy (achondroplasia) exhibits multiple epiphyseal deformities of the bones and joints The hands may be deformed with broad fingers and swelling at the interphalangeal joints The bones are thickened and the epiphyseal plates widened

Myositis ossificans progressiva is a disorder in which there is true bone formation throughout all the sheaths of the voluntary muscles In 75 per cent of cases there are short fingers and short abducted thumbs due to reduced length of the bones and fusions of adjacent bones.

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increased density of the epiphyseal plate and a zone of rarefaction in the metaphysis adjacent to the epiphyseal line

Vitamin D deficiency produces an osteomalacia and a widened irregular concave epiphyseal line

Fig 93

Fig 94

Figure 93 Seabright Bantam syndrome with shortened fourth and fifth metacarpals associated with pseudohypo-parathyroidism

Figure 94 Lead lines in epiphyseal plates.

Mineral Poisoning

The ingestion of lead by children results in linear bands of increased density along the growing ends of long bones (Fig 94) In adults such lead deposition can be seen in healing fractures or other areas of regenerating bone Bismuth produces similar changes in growing bone

Blood Disorders

Mediterranean or erythroblastic anemia may exhibit characteristic changes in the hands of children The metacarpals and phalanges assume a rectangular outline with dense web-like trabeculations and a markedly thinned cortex

Leukemia may show diffuse or localized areas of bone destruc

Endocrine Disturbances

The effect of various endocrines on bone is mediated through growth changes or calcium metabolism

The pituitary acts essentially on bone growth Overactivity will lead to gigantism if it occurs before closure of the epiphyses After epiphyseal closure such hyperfunction leads to acromegaly with elongation of the bones of the hand and hyperostosis of the tufts of the terminal phalanges Hypogonadism results in delayed epiphyseal closure (Fig 92) Hypothyroidism causes a defect in epiphyseal growth in which there are multiple centers of ossifica tion seen on x ray as stippling This delays longitudinal growth but lateral growth continues producing wide short bones. In Mongolism there is often a shortening of the middle phalanx of the fifth finger which is bowed toward the midline

Hyperthyroidism with its increased catabolism and subsequent protein depletion leads to osteoporosis Postmenopausal hypogonadism leads to osteoporosis due to lack of stimulation of the osteoblasts. Cushing s disease produces an excess of a steroid which inhibits anabolism of protein including bone matrix.

Primary hyper parathyroidism with its elevated serum calcium lowered serum phosphorus and negative phosphorus and calcium balance will show a progressive generalized osteoclasis of bone X ray will show decalcification cysts and occasionally osteoclastomas or giant cell tumors Changes may appear in the hand with the loss of density of all the bones and cysts in the phalanges

Hypoparathyroidism does not produce bone changes in the hand. Pseudohypoparathyroidism associated with tetany achon droplasia soft tissue calcifications mental retardation and low blood calcium and elevated phosporus levels not changed by parathyroid hormone has characteristic hand changes (Seabright Bantam syndrome) The metacarpals particularly the fourth and fifth are short and broad (Fig 93)

Vitamin Deficiencies

Lack of Vitamin C (scurvy) leads to a deficient bone matrix and may be recognized at the lower end of the radius and ulna by a general ground glass appearance of the bones widening and

Rheumatoid arthritis usually begins in the proximal inter phalangeal joints with development of typical fusiform swelling At a later stage the metacarpophalangeal joints may be affected There is gradual loss of articular cartilage as evidenced by narrowing of the joint space Decalcification of bone occurs particularly adjacent to the affected joint (Fig 95) In association with the joint changes there may be a weakness of grip due to atrophy of the intrinsic muscles With progress of the disease there is increasing deformity with flexion contractures of the metacarpophalangeal joints ulnar deviation of the fingers and adduction of the thumb

Figure 95 Rheumatoid arthritis demonstrating thinning of involved joint spaces, decreased bone density and ulnar deviation of metacarpophalangeal joints

Kestler[26] reviewed the pathology of arthritis and found that there was usually an inflammatory lesion in the muscles with the cell elements consisting of lymphocytes plasma cells epitheloid cells and occasionally mononuclears eosinophiles and polymorphonuclear cells. These cells usually had a nodular arrangement but occasionally a scattered infiltration was observed At the same time the muscles demonstrated degeneration as evidenced by enlargement increase in number and vacuolization of the nuclei

tion Occasionally periosteal stimulation may lead to bone production

Aseptic Necrosis

Osteochondritis dissecans occasionally has been found in the interphalangeal joints Ramsay and Batch[33] report the case of a fourteen year old boy who complained of pain and swelling of the interphalangeal joint of the left thumb X ray showed a lesion compatible with osteochondritis of this joint Operation revealed a small detached bone fragment which was dissected free and the involved indented base or bed of the lesion was curretted from the lateral margin of the articular surface

Kienbock s disease is an avascular necrosis of the lunate bone Dornan[18] reports forty-six cases forty three of which could be traced Forty were male and three female thirty-eight were heavy workers and five light. The right wrist was affected in twenty four cases and the left in nineteen Twenty two cases were treated conservatively with immobilization for three to four months Sixty three per cent returned to work When the lunate bone was excised 69 per cent of the patients returned to full work He believes that removal of the lunate bone is justified in the few cases where there is no gross osteoarthritis and where aching pain persists after efficient mobilization for three to four months

A similar disease occurs in the scaphoid and is known as *Preisser's disease*

Avascular necrosis of the phalanges of the hands or *Thiemann s Disease* affects the interphalangeal joints of the fingers and is noted in late childhood and adolescence There usually is pain in the involved joint with a fusiform swelling and some restriction of movement Due to the aseptic necrosis of the involved epiphysis, the phalanx is retarded in growth Toward the end of puberty the epiphysis regenerates and at the normal time joins with the metaphysis The end result is a moderate thickening of the epiphysis and metaphysis and a slight shortening of the phalanx.[34]

JOINTS

Joint diseases produced by specific bacteria have been discussed in the section on infections

If the interosseous muscles are mildly contracted, the flexion contracture of the metacarpophalangeal joint may be relieved by tenotomy of the lateral bands. If dislocation has been produced by the flexion deformity of the metacarpophalangeal joint which can be reduced passively, the metacarpophalangeal joint is left intact but the base of the metacarpal bone should be removed and fixed with Kirschner wires. If passive reduction of the dislocation cannot be produced, it will be necessary to perform an arthroplasty with excision of the metacarpal head. The new joint should be pinned in alignment until enough fibrous tissue contracts around it to give some stability.

If the thumb adduction is severe, the usual principles of treatment consist of cutting across the web, excising the contracted tissue, and applying a skin graft across the web. If there is no musculature left, a bone block will be needed for opposition of the thumb.[42] Further discussion of thumb contractures may be found in the section on reconstructive surgery.

When the metacarpal bones are shortened or when an arthroplasty is performed on the metacarpophalangeal joints, Bunnell[42] suggests that the extensor tendon should be lifted from the dorsal aponeurosis and transferred into a slit in the aponeurosis on the radial side of the knuckle. The extensor indicis proprius may be transferred to the radial side of the index finger and the extensor digiti quinti proprius can be used for the fifth finger. In this way the ulnar deviation may be corrected.

If a flexion deformity of the wrist has occurred, an arthrodesis of the wrist placed in a position of function is the procedure of choice.[43,44]

Hypertrophic arthritis may produce tenderness and swelling in the interphalangeal joints. X-ray will reveal bony spurs and osteophytes around the joint margins. Herberden's nodes are hypertrophic deformities seen on the dorsum of the terminal phalanges. As the disease progresses there may be destruction of joint cartilage, eburnation of articular surfaces and dislocation. True ankylosis does not occur in this disease which causes few symptoms.

Muscle fibers were found to be shrunken and broken up into small elements Many others were replaced by fatty and fibrous connective tissue The blood vessels showed a thickening of the walls with collagen and peri-or para adventitial round-cell infiltration At the same time changes in the collagenous tissues were observed with swelling of the ground substance and fibrinoid changes in the connective tissue These changes involved the extensor mechanism subcutaneous tissue joint capsule connective tissue septa and the intrinsic muscles.

There are many reasons given for the ulnar deviation of the fingers but it would appear to be due to several forces such as wasting of interossei and lumbrical muscles and the loss of stability in the metacarpophalangeal joints In addition the proximal interphalangeal joints usually demonstrate limitation of motion so that the patient cannot oppose the fingertip to the thumb tip As a consequence when the patient tries to grasp an object with his fingers, he opposes his thumb against the proximal interphalangeal joint. This pressure together with the previously mentioned laxity of the metacarpophalangeal joints eventually will lead to the thumb pushing the fingers in an ulnar direction

Absorption of the bone near the joints may become so severe in rare cases that the fingers and wrist are shortened and the skin wrinkled and thrown into folds giving the impression that the phalanges have retracted into each other like an opera glass. At this stage of the disease instead of limitation of motion there is abnormal range of motion in all directions [39]

Rheumatoid nodules may develop in the subcutaneous tissues over bony prominences near the joints and occasionally a nodular polytendovaginitis can occur [40] Sometimes the hands of such patients are cold and there is evidence of poor blood supply Leb [41] performed angiographic studies on arthritic patients and found in all cases that there is a relatively marked ischemia of the fingers as compared to the normal

It is beyond the scope of this book to discuss the treatment of rheumatoid arthritis by the usual methods of splinting and steroid therapy In later stages of the disease when the inflammatory process has essentially burned out there may be a place for surgery in restoring function to these crippled hands

and changes were found in the various bones of the wrist believed to be due to continued hard labor[51]

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OCCUPATIONAL STIGMATA

Besides revealing much of a patient's medical history the hand will portray an occupation or hobby Numerous treatises have been written on this subject so that only a few examples will be mentioned

The hand is exposed to various mechanical physical chemical and biological agents in the course of work or play which result in calluses scars burns, stains tattoos skeletal and tendon deformities depending upon the occupation Schwartz *et al*[45] list the occupational stigmata from physical and mechanical causes in over fifty occupations Typical examples are calluses appearing on the palmar and ulnar surface of the little finger in bakers on the thumbs of basket makers on the thumbs and fingers of patients using shears on the fingertips of typesetters Thickening of the skin may appear on the fingertips of harp players on the right index fingers of yarn winders in the web space between the thumb and fourth finger in cotton mill doffers and on the finger tips of violinists Tenosynovitis crepitans is observed on the wrists of people using a continuous movement such as cane cutters gardeners and stenographers Tenosynovitis of the long extensor of the thumb may be seen in drummers The blue black tattooing of coal miners hands is an example of pigmentation produced by particles driven beneath the skin

Other examples of occupational stigmata appear in the recent literature Fernandez,[46] and Robertson[47] discuss what seems to be a bursa on the dorsum of the middle or terminal phalanx of the middle finger due to constant percussion in performing examinations Waxman and Geshelm[48] describe ten cases of Boxer's Bursitis over the metacarpophalangeal joints of professional boxers Due to the constant killing of rabbits by hyper extending the neck of the rabbit between the thumb and index finger a weakness of the collateral ligament on the ulnar side occurred in twenty four gamekeepers[49] A similar weakness of the radial collateral ligament of the proximal interphalangeal joint of the index fingers of plant potters has been reported[50] The hands of fifty people who worked with compressed air guns and of sixty who did hard physical work were examined

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(Fig 96) with little matrix to an almost acellular one with much collagen (Fig 97) The cellular pattern may so resemble a fibroma that the disease has been classified as a neoplasm [7,8] Lymphocytic infiltration and increased vascularity may be seen which has been interpreted by some as inflammatory and others as traumatic [8,11]

The plantar fascia is involved in approximately 3 per cent of patients with Dupuytren s disease [12,13] Knuckle pads over the proximal interphalangeal joints exhibiting a similar histologic pattern may be seen in approximately 10 per cent of cases [14] Rarely it may be associated with Peyronie s disease [15,16]

The etiology of Dupuytren s contracture is still in dispute An inherited disposition has been demonstrated in as high as 40 per cent of some series [11,17,20] Long family histories and the occurrence in identical twins give further emphasis to this factor Graubard [21] found the blood factor Rh_1 Rh_2 present in all cases that he studied

Repeated trauma is another factor to be seriously considered even though the disease occurs as often in non laborers as in laborers Several series demonstrate a very high incidence among certain occupations brewery workers [2] textile workers [22] and telephone cable repairers [23] Graubard [21] found seventy-six cases in which Dupuytren s contracture developed after palmar laceration and in forty nine x rays revealed metallic foreign bodies near the fourth metacarpal bone

Rheumatic diathesis has been implicated by some investigators [10–4] However careful study of its incidence reveals no increase in patients with arthritis [4]

The occasional association of this disease with neurologic disorders such as epilepsy and herpes zoster has implicated this system [11,23,26] Scholz [27] found a compression of single or multiple intervertebral foramina between C5 and C6 in 87 per cent of seventy cases and believes this compression produces a sympathetic nervous system disturbance A sympathetic reflex has been described to explain the occurrence of Dupuytren s contracture with myocardial infarction [28,29] However no increased incidence has been found among epileptics or coronary disease patients [4]

Hines [30] reports Dupuytren s contracture with Raynaud s phenomenon following isoniazid therapy Paletta [31] finds a decreased vasomotor reactivity in fifteen cases of Dupuytren s con

CHAPTER 13

FIBROUS HYPERPLASIA

There are many hand conditions which have a basic pathologic pattern of fibrous tissue hyperplasia. Although trauma may play a role in their development, they can occur in its absence. Therefore they are placed in this chapter to emphasize that their basic nature is unknown.

DUPUYTREN'S CONTRACTURE

Sir Astley Cooper (1822) described this contracture and advised a subcutaneous division of the contracting bands. However it remained for Dupuytren (1832) to clearly demonstrate that the process was localized to the palmar fascia and not to tendons. Since then much progress has been made in its treatment but relatively little in its etiology or pathogenesis.

Athough this contracture is present in approximately 2 per cent of the population, individual series range up to 47 per cent.[1,3] It usually appears after the age of forty but may appear at any age. Although it is generally recognized that males are effected most, recent investigation casts doubt on such an impression. In a study of 2,705 patients in various Toronto hospitals, an equal incidence was found in both sexes in all age groups.[4]

The prominent histologic pattern is a fibroplasia of the pretendinous bands of the palmar fascia. This process may extend into the overlying skin and adjacent fatty tissue and proceed along the palmar fascia septa to the interosseous fascia and the superficial and deep fascia of the fingers. The involvement of the attachment to the proximal phalanx may produce an exostosis on the proximal phalanx.[5,6] The usual pathways of nerves and vessels are grossly distorted and offer a challenge to successful surgery. The process varies from a cellular fibroblastic tissue

tracture which indicates that more circulatory studies should be done since the only definite factor in all series of this disease is the relationship to age

Dupuytren s disease is reported to be higher among tuberculous patients than others[4] It has been discovered in 17 per cent of chronic alcoholics with cirrhosis and in 27 per cent without cirrhosis[3] However this was a selected population and there was no correction for age

The clinical picture develops at varying speeds Some never progress in twenty to thirty years while some proceed to a severe stage in a year The disease begins as a nodule in the palmar fascia just above the base of a finger The skin may become involved and be puckered As it extends into the proximal phalanx it produces a flexion deformity of the metacarpophalangeal and proximal interphalangeal joints (Fig 98) The fourth finger is most commonly involved followed by the fifth third second and thumb (Fig 99) Conway[19] studied several series and found the following distribution ring finger 1550 cases fifth finger 1299 fourth 570 index 135 and thumb 79

There are several classifications of the disease but Shaw s[2-] appears to be as satisfactory as any

Stage 1 A nodule in the palmar fascia not yet including the skin or a nodule in the skin with no change in the fascia.

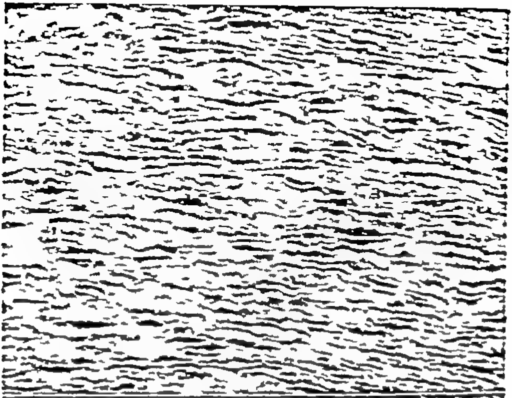
Stage 2 A nodule in the fascia involving the skin

Stage 3 Same plus a flexion contraction of one or more of the fingers

Stage 4 Same plus tendon and joint contracture

The disease may progress to permanent flexion deformities of the fingers with irreversible changes in the metacarpophalangeal and proximal interphalangeal joints About half the cases are bilateral and of the remainder the right is twice as frequently involved as the left.

Surgery is the treatment of choice but some forms of medical treatment have been tried Finney[22] used radium and found that 75 per cent of cases improved and in no case was the condition aggravated For severe disease he gives a total dose of 3000r to



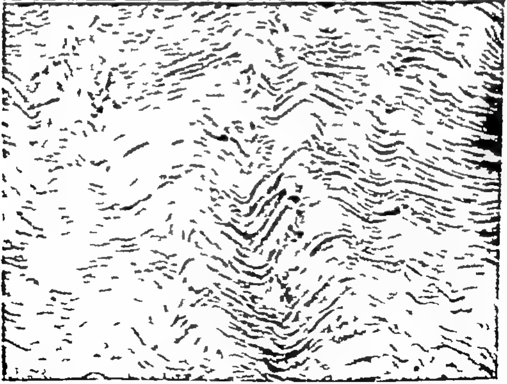


Figure 96. (Top) Dupuytren's contracture. Microscopic pattern of many fibroblasts and little collagen. (370x)

Figure 97. (Bottom) Dupuytren's contracture. Microscopic pattern of few fibroblasts and much collagen. (370x)

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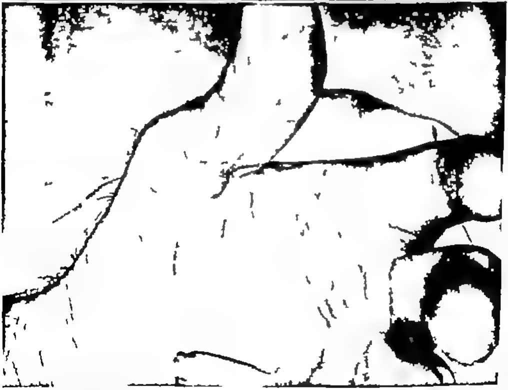

Figure 98 (Top) Dupuytren's contracture involving fourth and fifth fingers. Puckering of skin over fascia bands is evident.

Figure 99 (Bottom) Dupuytren's contracture involving thumb.

the skin The author cannot help but feel that radiodermatitis with the ever constant threat of carcinoma may be a complication of such treatment

Vitamin E treatment has been used with varying success [10,15,31,36] However other authors found no effect [37,40] This is an interesting phenomenon and certainly deserves more study It may have to do with the cellularity of the process since it is difficult to imagine how mature collagen can be affected by Vitamin E The usual daily dose is 200 mg of tocopherols which is maintained for several months

Cortisone has been used [41-45] It has limited value in the primary treatment but appears to play a beneficial role in postoperative mobilization either through its effect on contracted joints or postoperative fibrosis.

The most successful method of treatment is total extirpation of the palmar fascia Although some authorities advise this operation in early stages it is probably best to postpone surgery until it is evident that the disease is flexing a finger In order to permit meticulous dissection a bloodless field and either general anesthesia or brachial plexus block are mandatory Soderberg [46] still advises local anesthesia but there is little support elsewhere for this idea.

Although many incisions have been suggested for the fasciectomy [47-48] a very useful procedure combines a transverse distal palmar one with a proximal curvilinear one (Fig 100A) The proximal fascia is excised through an incision curving around the thenar crease (Fig 100B) Usually the remainder of the dissection can be carried out through a tranverse incision over the metacarpal heads (Fig 100C) The finger extensions offer the most problem Longitudinal or transverse flaps mid lateral bayonet and oblique incisions (Fig 100D) can be used depending upon the circumstances If the skin is markedly contracted a Z plasty is useful

The skin is carefully dissected off the underlying fascia and if it is severely diseased it should be excised and a full thickness skin graft applied at the end of the procedure. Bruner [49] advises a dorsal flap in such situations A dorsal flap is planned one side of which is the ulnar side of the defect This flap is shifted into

Figure 98 (Top) Dupuytren's contracture involving fourth and fifth fingers. Puckering of skin over fascia bands is evident

Figure 99 (Bottom) Dupuytren's contracture involving thumb

The palmar fascia is dissected away taking care to include the septa passing alongside the tendons down to the deep fascia The fascia on the involved proximal phalanx is similarly removed Since the arteries and nerves are often pulled far from their normal position by the disease process their preservation is difficult and requires careful meticulous dissection

The tourniquet is removed and hemostasis obtained following which the skin incisions are closed A firm pressure dressing is applied with the hand in the position of function This is left in place seven to ten days before active motion is begun To prevent postoperative hematoma or edema Tanzer[31] uses a compression suture as follows

"Before the skin incisions are closed a mattress suture of No 3-0 silk double armed on straight needles and incorporating a button is passed directly through the hand at two points. The first needle penetrates the skin between the second and third metacarpal bones passes under direct vision to one side of the neurovascular bundle and pierces the intermetacarpal space at a level far enough distalward to avoid the deep volar arch and ulnar nerve emerging through the dorsal skin The second needle is introduced in the same manner between the fourth and fifth metacarpal bones After the wound closure is completed packing is carefully introduced beneath and around the silk loop in the palm and the button is drawn onto the packing by gathering up on the dorsum of the hand the two suture ends which are threaded through a second button and tied with moderate firmness over gauze to maintain snug pressure

Postoperative cortisone may aid in mobilization of joints Parenzyme (1 c c. b i.d) for the day of operation and three succeeding days and (1 c.c. daily) for three days may eliminate edema. Postoperative x ray has been advised but is of dubious value [48,82]

Amputation of a digit is done if there are severe joint changes with subluxation [81] This is particularly true in the older patient when the prolonged postoperative immobility may affect motion of the uninvolved fingers However the patient's occupation must be considered since a patient may have a more functional hand with a hooked little finger than without any finger

place and the resulting dorsal defect covered with a split thickness graft. Skinner[30] uses a tunnel graft in such instances If amputation of a digit is planned because of severe joint disease the bone can be removed from the finger and the skin of the digit used as a flap graft to cover a possible palmar defect

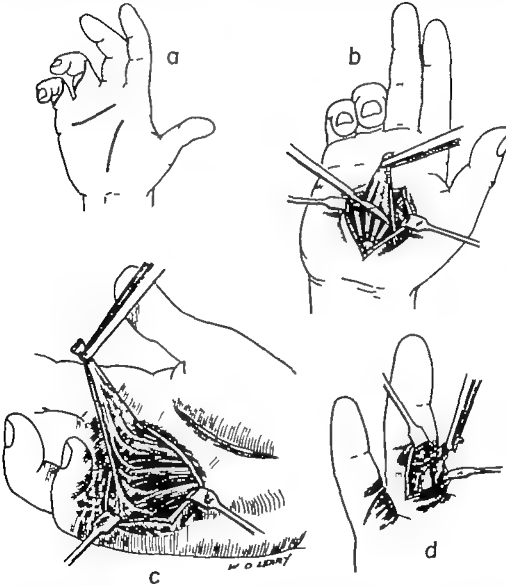

Figure 100 Excision of palmar fascia. (A) Diagram of a useful series of incisions (B) Dissection of proximal portion of palmar fascia through thenar incision (C) Dissection of central and distal portion of palmar fascia through transverse incision along palmar crease Septa should be excised down to deep interosseous fascia Nerves and arteries which are lying in distorted positions should be meticulously avoided (D) Dissection of phalangeal extension of diseased fascia through curvilinear incision

STENOSING TENDOVAGINITIS

This disease is an inflammatory condition of the fibrous tendon sheaths. *The involved sheath becomes thickened from fibroplasia* and adhesions may develop on the internal surface. The involved tendons become thinned out at the points of constriction, and proximal to this area they may be bulbous. Microscopically there is marked fibrosis with a scattered collection of lymphocytes (Fig. 101). At times the fibrosis proceeds to such a degree that the connective tissue is hyalinized and occasionally cells resembling cartilage can be seen.[29]

Lapidus and Fenton[30] reviewed 423 cases and found the following distribution of tendon sheaths:

Tendon Sheath	*No. of Sheaths*	*% of Total*
Sheath of the abductor pollicis longus and extensor pollicis brevis	165	39.0
Sheath of flexor pollicis longus	135	31.9
Flexor sheath of 2nd finger	4	1.0
Flexor sheath of 3rd finger	44	10.4
Flexor sheath of 4th finger	46	10.9
Flexor sheath of 5th finger	16	3.8
Sheath of extensor pollicis longus	6	1.4
Sheath of extensor carpi radialis longus	2	0.5
Sheath of extensor carpi radialis brevis	2	0.5
Sheath of flexor carpi radialis	1	0.2
Sheath of extensor to 2nd finger	1	0.2
Sheath of extensor to 5th finger	1	0.2

As can be seen the sheaths of the abductor pollicis and flexor tendons are in the majority. However, other authors have reported on unusual locations such as the extensor pollicis brevis alone, the flexor carpi radialis, the extensor carpi radialis, the six dorsal compartments of the wrist as well as in the flexor carpi radialis and in the tendons of the foot and ankle.[60-66]

The disease usually occurs between the ages of thirty and sixty although there are numerous cases reported in children.[67-70] It has been found in 75 per cent of females and 25 per cent of males. The cause of the disease is unknown, but it appears to

An occasional hopelessly contracted and subluxed finger may be salvaged by the Hutchinson procedure After the aponeurosis has been excised the base of the proximal phalanx is removed and the extensor tendon shortened.

Subcutaneous tenotomy under local anesthesia still has adherents but the danger of nerve and artery damage contradicts its general acceptance except as a preparatory procedure to excision when the involved fingers press into the palm and interfere with the operation [84, 85]

Limited excision is of value in the elderly patient when the radical operation might produce marked limitation of motion in the entire hand [86] Longitudinal or serpentine incisions are utilized

The results of radical excision are quite good and the recurrence rate is low However the hand may lose as much as 25 per cent of its gripping power [87]

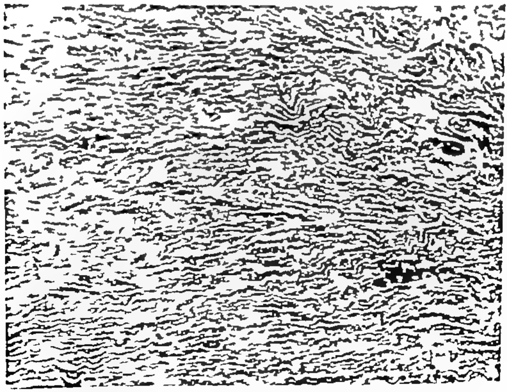

Figure 101 Stenosing tendovaginitis. Microscopic section showing few fibroblasts and much collagen (170x)

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be an inflammation occurring from repeated motion in aging fibrous tissue Almost every case presents some occupational motion The condition is more prone to develop in a new worker unaccustomed to the job an old worker out of training returning to his task after a period of idleness or a worker who is asked to speed up output to meet a new production quota.[69] Of interest in this connection is Sperling s[71] attempt to produce the disease in himself by flexing the little finger of his right hand 9 000 times over a period of seventy two hours He developed jerky movements and palpable thickenings on the terminal and proximal phalanges Two months later the tendons could still be felt to jerk and snap He did the same with the extensor pollicis longus and abductor pollicis longus tendons He came to the conclusion that numerous small movements may lead to the condition However from his description it would appear that this was more apt to be a traumatic tendinitis than a tendovaginitis. Three cases have been reported wherein the trauma appears to be exposure to high temperature[72] It is obvious that all cases are not occupational since the disease occurs in infants

When the flexor tendons of the fingers are affected the disease is known as *trigger finger* or *trigger thumb* At first there is pain on movement of the fingers and eventually a snapping may be felt and heard as the finger is extended and flexed. If the disease continues the finger may be locked in flexion or extension Associated with this there will be tenderness over the metacarpal head of the involved finger at the site of the disease process and a bulbous enlargement of the tendon may be felt

It is well to remember that other disease processes may produce locked fingers Langenskiold[73] reports several cases of habitual locking of the metacarpophalangeal joint of a finger when the collateral ligament is caught in the groove over the capitulum of the second metacarpal bone Burman[74] reports a flexion contracture of the proximal joint of a finger due to a tear of the third lumbrical muscle The distal portion of the muscle had locked the tendon against the digital sheath by fibrous tissue

Treatment consists of incision of the constricting area of the tendon sheath through a small transverse skin incision over the head of the metacarpal

Stenosing tendovaginitis of the tendon sheath of the abductor pollicis longus and the extensor pollicis brevis was first clearly recognized by *De Quervain* (1895) In this process an additional etiological agent is supposed to be the presence of accessory tendons in the tendon sheath However this is such a common anomaly that it is doubtful if it plays a significant role The disease is manifested by pain and tenderness over the styloid process of the radius Motion of the thumb produces pain particularly on flexion When the thumb is held flexed within the fist and the hand ulnarly deviated there is marked pain in the involved site [7] There may be swelling and erythema over the involved tendons Snapping or locking is never seen in this disease

Standard treatment is incision of the constricted tendon sheath throughout its entire length (Fig 102) It is well to remember that the extensor pollicis brevis may pass through a separate fibrous tunnel and if it is involved in the process it should similarly be incised Recurrences have occurred when this is overlooked [61] The

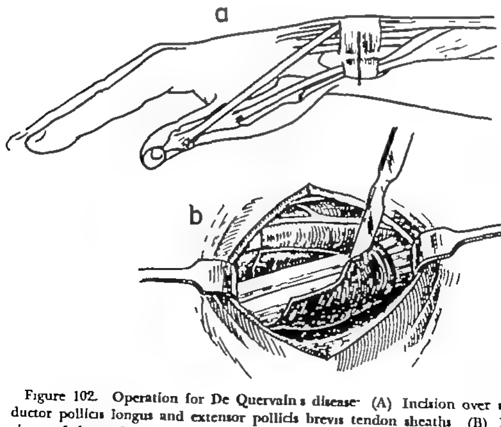

Figure 102. Operation for De Quervain's disease (A) Incision over abductor pollicis longus and extensor pollicis brevis tendon sheaths (B) Incision of diseased tendon sheath throughout its entire length.

sheath may be incised through a transverse incision in one of the dorsal wrist creases over the involved area. The only difficulty with this incision is the occasional occurrence of a traumatic amputation neuroma To obviate this a longitudinal incision may be used[76]

Occasionally a cure results from three or four weeks of immobilization in a plaster-of Paris cast. However the author has seen one case where this prolonged treatment resulted in such dense adhesions of the extensor tendon in the groove that motion of the thumb was markedly interfered with even after surgery

X ray treatment of the lesion has been advised and recently there has been some interest in cortisone injections[71,77] After observing twenty cases treated by hydrocortone injections it is my belief that this may be tried once or twice If repeated and prolonged trials are necessary however the continued immobility may result in limitation of thumb and wrist motion

TRAUMATIC TENDINITIS

Prolonged usage of a tendon which slides through a narrow groove may result in an inflammation of the involved tendon This becomes painful on use and may exhibit snapping and crepitation A common site for this is the tendons of the extensor carpi radialis brevis and longus Treatment consists of immobilization for three to four weeks

A variant of this condition consists of an inflammation at the insertion of a tendon into bone which may be associated with calcific deposits Such *calcific tendinitis* or *peritendinitis calcarea* has been the subject of numerous case reports[78] [illegible] The disease has become so well known that 100 consecutive cases of this syndrome has been reported[illegible] The most common tendon involved [illegible] the insertion of the carpi ulnaris but it may affect any tendon in the hand including the tendons of the interosseous muscles

The clinical pattern is a sudden acute pain in the involved area which increases in severity and is often associated with swelling and erythema The involved part is held in a position of physiologic rest and usually one finds poignant tenderness over the tendinous insertion X ray will demonstrate the calcific deposit (Fig 103)

In Carroll's series the average age is forty five with the largest number occurring from thirty to sixty. Thus this process may be similar to stenosing tendovaginitis, i.e. a wear and tear phenomenon on aging fibrous tissue. These cases were treated by local injection with one per cent procaine and warm water soaks. Occasionally these authors have been forced to operate on the calcium deposit and found the pain to subside within twenty four hours. The average time for relief of pain in most cases was nine days and the average time of disappearance of the calcium deposits was approximately fourteen days although in many it lasted three or four months.

Figure 103. Calcific deposit over volar surface of metacarpophalangeal joint of thumb associated with exquisite tenderness and swelling

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CHAPTER 14

TUMORS

SKIN

Epidermoid or *implantation cysts* commonly appear in laborers and are found on the palmar aspect of the hand or fingers confining themselves solely to the skin (Figs 104 and 105) The consensus of opinion is that they are due to implantation of surface epithelium into the deeper layers of the skin by trauma Microscopic section of the walls of these cysts demonstrate fibrous tissue with an inner layer of squamous epithelium which may show laminated keratin (Fig 106) No sebaceous material is present Treatment is complete surgical excision (Fig 107)

Epidermoid cysts occasionally may involve bone in which case x ray examination will show an area of osteolysis in the involved bone usually the terminal phalanx of the finger The cortex will be expanded and thinned but there is no evidence of periosteal proliferation Treatment is excision of the involved bone Curettage may cure a small cyst [1-4]

Sebaceous cysts may occur on the dorsum of the hand or fingers Treatment is surgical excision by means of an elliptical incision over the involved part after which the cyst is excised without spillage of sebaceous material The entire cyst is excised since a remnant may produce recurrence

Mucous cysts are myxomatous lesions believed to be due to mucoid degeneration of the dermis They are found on the dorsal aspect of the fingers near the distal interphalangeal joint the long finger being most commonly involved (Figs 108-109) The great majority occur in women These cysts appear as translucent painless nodules some of which may be multiple The process begins as a mucoid change in the dermis and as it continues the cells become widely separated from each other with the center becoming fluid With further progress the amount of recogniz

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radiation Other factors may be exposure to a carcinogenic agent such as coal tar and oil derivatives or internal arsenical treatment It also may occur in burn scars or at the site of chronic infections such as osteomyelitis

Invasion of the underlying tissues by this tumor is impeded by the supratendinous layer of fascia and fixation of this structure may be inflammatory rather than neoplastic However in time it will cross this barrier invading underlying muscles nerves, bones and tendons The most frequent metastasis is the axillary lymph node group but occasionally the epitrochlear nodes are involved Johnson and Ackerman[9] studied the factors influencing metastasis and believe that the most important single factor is the depth of invasion of the skin They have not had metastasis unless the carcinoma extends below the level of the sweat glands Other factors such as size of the tumor and histologic differentiation may be of influence

Treatment consists of wide excision with skin grafting of the

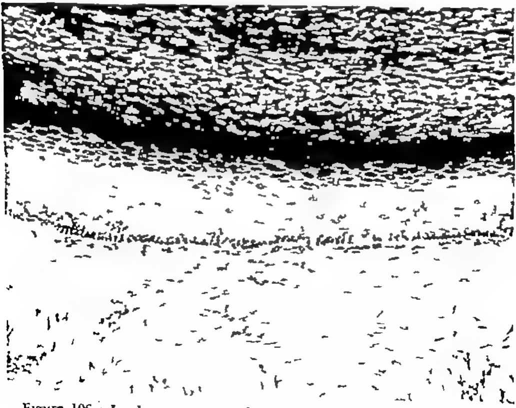

Figure 106 Implantation cyst Microscopic section showing wall of fibrous tissue and stratified squamous epithelium (100x)

able mucoid tissue disappears so that in well developed cysts there is a clearly defined wall lined by modified connective tissue in contact with the fluid material of the cyst [88] The recurrence rate is high unless a wide margin of skin is removed around the lesion with the resulting defect covered by a split thickness skin graft. Regression of these cysts with x ray treatment has been reported [78]

Squamous carcinoma occurs most commonly on the dorsum of the hands of patients in the age group of seventy or older (Fig 110) Causative factors are excessive exposure to sun and

Figure 104 (Top) Implantation cyst on palm.

Figure 105 (Bottom) Implantation cyst on finger

radiation Other factors may be exposure to a carcinogenic agent such as coal tar and oil derivatives or internal arsenical treatment It also may occur in burn scars or at the site of chronic infections such as osteomyelitis

Invasion of the underlying tissues by this tumor is impeded by the supratendinous layer of fascia and fixation of this structure may be inflammatory rather than neoplastic However in time it will cross this barrier invading underlying muscles nerves, bones and tendons The most frequent metastasis is the axillary lymph node group but occasionally the epitrochlear nodes are involved Johnson and Ackerman* studied the factors influencing metastasis and believe that the most important single factor is the depth of invasion of the skin They have not had metastasis unless the carcinoma extends below the level of the sweat glands Other factors such as size of the tumor and histologic differentiation may be of influence

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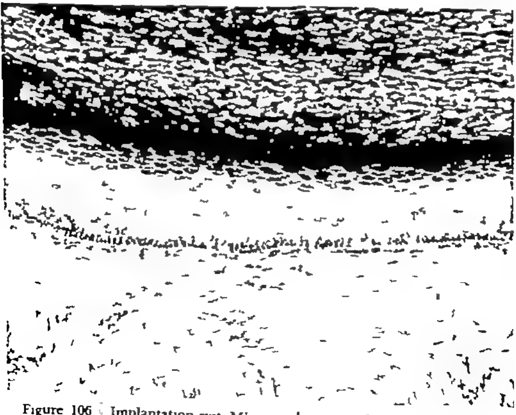

Figure 106 Implantation cyst. Microscopic section showing wall of fibrous tissue and stratified squamous epithelium. (100x)

Figure 107 (Top) Excision of implantation cyst.

Figure 108 (Bottom) Mucous cyst on dorsum of distal phalanx of middle finger (Courtesy Dr John Grandon.)

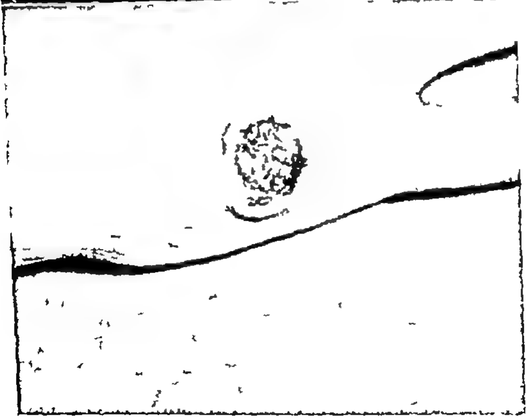

Figure 109 (Top) Mucous cyst on dorsum of middle phalanx of ring finger

Figure 110 (Bottom) Squamous carcinoma on dorsum of hand

resultant defect Amputation is performed only if there is in volvement of underlying structures Prophylactic axillary dissec tion is of no value but radical axillary dissection is done when nodes can be palpated Using this method of treatment, a 93 per cent survival rate was found in 136 cases where lymph glands were not involved and a 66 per cent survival rate when positive nodes were present.[10]

Basal carcinomas rarely appear on the hand Only eighteen basal cell lesions on the upper extremity are reported as com pared to 163 squamous carcinomas [10] Of 237 cases of rodent ulcers treated only two appeared on the hands [11] Treatment consists of excision with skin grafting

Carcinoma of the nail bed may occur the majority of which are squamous with a few of basal cell origin Because of the close proximity to bone it is more often involved by these lesions than by the average carcinoma of the hand Treatment consists of amputation of the finger with axillary dissection performed when the nodes are palpable,[12,13]

Sweat gland adenomas occasionally occur on the hand as rubbery one centimeter growths in the skin Histologically they show nests or cords of cells with clear or eosinophilic cytoplasm with well stained nuclei (Fig 111) The cells may be arranged in radial fashion Sometimes they may be malignant and must be treated as other types of skin cancer (Fig 112) [14]

Melanomas are of debatable origin but most modern observers agree that they arise from the junctional nevus [15] This is a hair less, smooth flat-to-slightly raised brown nevus which histo-logically reveals neval cells in the basal layers of the epidermis (Fig 113) The intradermal nevus which represents the ordinary mole and which may occasionally demonstrate hair shows the nests and sheets of neval cells in the dermis with no implication of the overlying epidermis (Fig 114) These tumors are not pre malignant. An occasional nevus is compound demonstrating both intradermal and junctional changes

Nevi on the palmar surface as well as any which become larger more pigmented or irritated with ulceration and bleeding should be excised as potential malignant lesions. They are ex cised with a wide margin in order to prevent recurrences

Melanomas arising in the hand constitute about 1 to 5 per cent of all melanomas occurring in the body They may occur in the subungual region giving rise to the so-called *melanotic whitlow* which often is mistaken for a paronychia (Fig 115) The palm and other areas of skin are less commonly involved

Lymphatic spread of these lesions is to the epitrochlear and axillary nodes and blood stream invasion is chiefly to the liver and lungs although any organ in the body may be involved

Treatment consists of wide local excision including underlying fascia with a margin of about six to eight centimeters around the lesion This necessitates an amputation for a subungual melanoma Four to six weeks later a radical axillary dissection should be performed If the disease completely permeates the lymphatics of the arm and axilla it may be necessary to do a fore-quarter amputation [18]

In a study of 744 cases the over-all five year survival rate for melanomas was 21 per cent.[18] It is of interest that the palmar

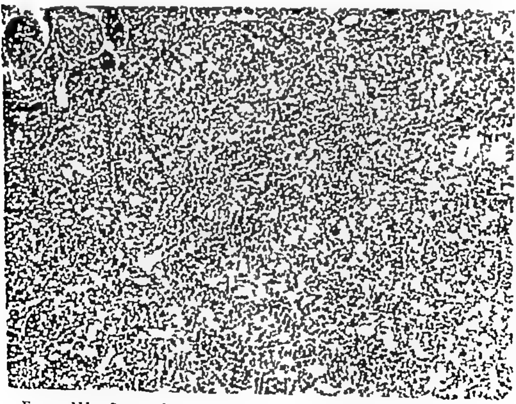

Figure 111 Sweat gland adenoma. Miscropic section showing nests of cells with eosinophilic cytoplasm. (100x)

resultant defect. Amputation is performed only if there is involvement of underlying structures. Prophylactic axillary dissection is of no value but radical axillary dissection is done when nodes can be palpated. Using this method of treatment, a 93 per cent survival rate was found in 136 cases where lymph glands were not involved and a 66 per cent survival rate when positive nodes were present.[10]

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Nevi on the palmar surface as well as any which become larger, more pigmented or irritated with ulceration and bleeding should be excised as potential malignant lesions. They are excised with a wide margin in order to prevent recurrences.

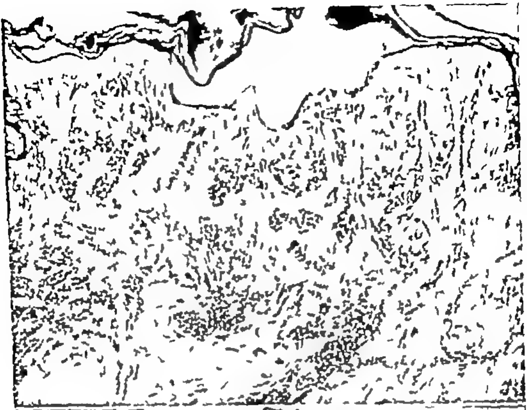


Figure 113 (Top) Junctional nevus Neval cells can be seen in the basal layers of the epidermis. (100x)

Figure 114 (Bottom) Intradermal nevus. Neval cells confined to dermis. (100x)

lesions had an 87 per cent survival rate of eleven cases and the subungual lesions a 39 per cent survival in twenty four cases With subungeal lesions the amputation of a digit gives a wider excision than the usual excision of a melanoma. In the palm the lesions are rapidly brought to attention

Figure 112. Sweat gland carcinoma.

CONNECTIVE TISSUE

Fibromas may occur in various locations on the hands (Fig 116) When they appear over palmar fascia they may be confused with Dupuytren s contracture Occasionally they are multiple in nature Twenty-two cases of symmetrical fibromas localized over the metacarpal or interphalangeal joints have been reported [17] They are commonly found in females in the age group of ten to forty Treatment is excision and they seldom recur Keasbey [18] reported a fibroma which shows a marked tendency to recurrence (Juvenile Aponeurotic Fibroma) This occurs in the palm or soles of small children and tends to recur after excision There is a histologic impression of cellularity and invasiveness

Fibrosarcomas rarely occur in the hand Five hand fibrosarcomas have been found in a series of forty five cases [19] These behaved as all other fibrosarcomas with spread by local invasion and blood stream dissemination Treatment is by wide radical excision

Lipomas commonly occur on the dorsum of the hand where

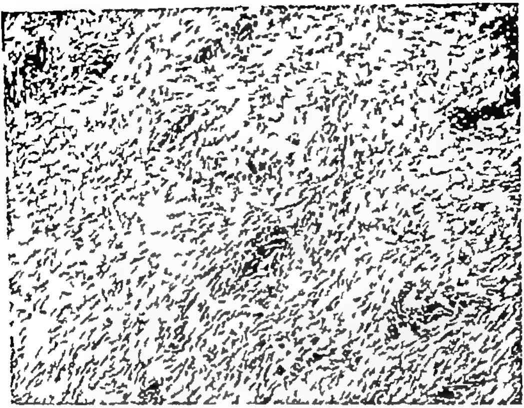


Figure 116 (Top) Fibroma (100x)

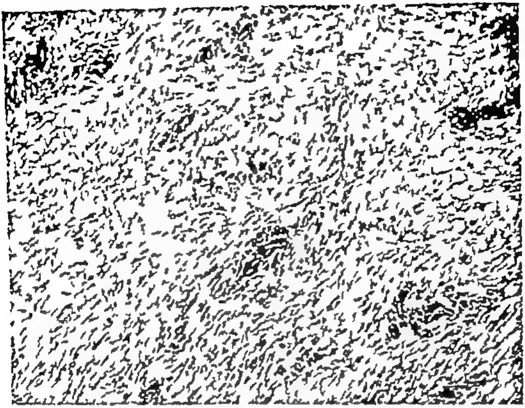
Figure 117 (Bottom) Ganglion Microscopic section of fibrous wall (100x)

they may be confused with tenosynovitis A rare type of lipoma occurs in the palm with approximately twelve having been reported to date [20]

JOINTS AND TENDON SHEATHS

Ganglions are common cystic tumors in the hand They are a mucoid degeneration of the connective tissue of the joints similar to adventitious bursas [21] Their etiology is unknown but trauma occasionally may play a role in their development Histologically they are composed of a fibrous connective tissue wall with contents resembling soft jelly (Fig 117) They never become malignant. The most common locations are on the dorsal aspect of the wrist between the long extensor of the thumb and the index finger in the anatomical snuff box at the base of the thumb The volar ganglion may be seen between the tendons of

Figure 115 Melanotic whitlow or sub-ungual melanoma. (Courtesy Dr John Crandon)



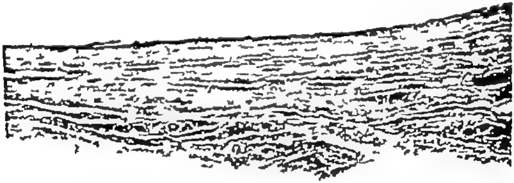


Figure 116 (Top) Fibroma (100x)

Figure 117 (Bottom) Ganglion Microscopic section of fibrous wall (100x)

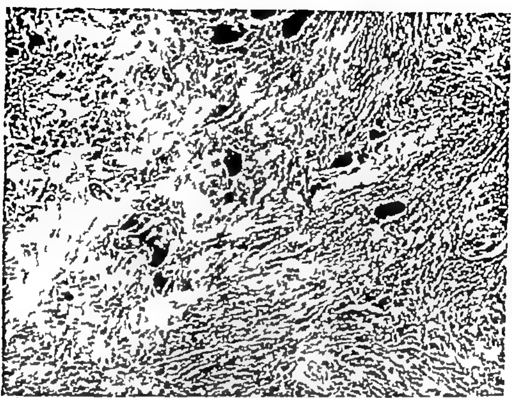
the flexor carpi radialis and brachioradialis (Fig 118) In this particular location care must be taken to avoid damaging the radial artery at the time of surgery They also may be seen on the fibrous sheaths of the long flexor tendons of the fingers and occasionally on the dorsum of the interphalangeal joints Treatment is indicated when they cause pain or are of such size as to be cosmetically distasteful Although various treatments have been advocated the best is surgical excision in a bloodless field. A flange of joint capsule around the base of the tumor is excised to prevent recurrences Surgical skin incisions should be transverse but care must be taken particularly with dorsal ganglions to avoid damaging the sensory branches of the radial nerve.

Synovial sarcomas consist of two elements synovial and fibrous tissue. The fibrous element appears as spindle shaped cells similar to those seen in fibrosarcoma The synovial cells are arranged in cords or sheets and may be cuboidal and columnar and line slit like spaces (Fig 119) These cells secrete material which stains with mucicarmine They arise from joints tendon sheaths or bursa but seldom project into the synovial cavity Spread is by local expansion and infiltration with eventual spread by the blood stream to the lungs The regional lymph nodes are in

Figure 118 Ganglion on volar surface of wrist

Figure 119 (Top) Synovial sarcoma Synovial cells lining slit like spaces surrounded by fibroblastic tissue (100x)

Figure 120 (Bottom) Giant cell tumor of tendon sheath. Polygonal basophilic cells embedded in eosinophilic stroma. (100x)



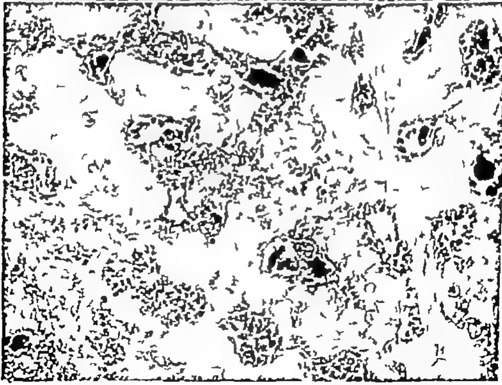


Figure 121 (Top) Giant cell tumor of tendon sheath Characteristic giant cells. (100x)

Figure 122. (Bottom) Giant cell tumor of tendon sheath Stroma resembling cartilage (100x)

volved in about 20 per cent of cases A review of the literature on this tumor revealed only four five year survivals among 143 cases[22] Approximately 5 per cent of such tumors occur on the hand Treatment is by wide surgical excision

Giant cell tumors (xanthomas) are tumors which histologically show an eosinophilic collagenous stroma in which is embedded the characteristic cell a polygonal cell with rather scanty basophilic cytoplasm (Fig 120) It has a large nucleus in which there may be prominent nucleoli The giant cell which gives this tumor its name, is seen in various numbers with nuclei ranging from four to fifty or sixty (Fig 121) The stroma may resemble cartilage (Fig 122) Foam cells and hemosiderin pigment are fairly constant features (Fig 123)

Sixty six of these tumors seen at the Boston City Hospital from January 1945 to June 1956 were reviewed Fifty-six occurred in the hand and ten in other areas of the body, three from the knee three the forearm and four the ankle Forty three (63 per cent) occurred in women and twenty three (27 per cent)

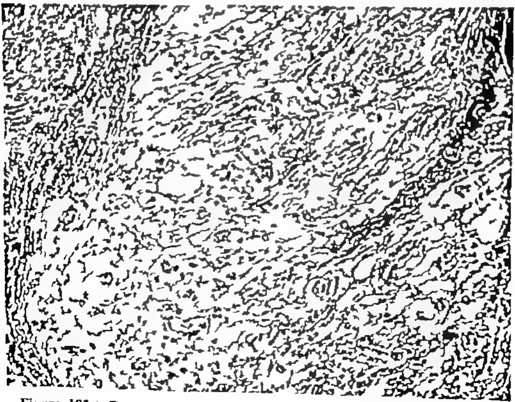


Figure 123 · Giant cell tumor of tendon sheath Typical foam cells. (100x)

in men. Approximately 75 per cent occurred in the age group of thirty to sixty nine

In thirty-one cases where accurate records were kept seventeen occurred on the volar surface and fourteen on the dorsal surface of the hand and fingers (Fig 124) The tumors occurred on the right hand in twenty three cases and the left in twenty-eight. No record was kept of the remaining cases In only two cases was the tumor situated on the volar surface of the palm and in the remaining it occurred along the fingers Of fifty three cases where accurate records were kept the thumb was involved six times index finger seventeen middle thirteen ring four fifth thirteen The exact location along the finger was recorded in thirty five cases and they were more frequent in the proximal and distal portions of the fingers with the middle portion being relatively free The distribution of these thirty five recorded cases was metacarpophalangeal joint five, proximal phalanx twelve proximal interphalangeal joint two middle phalanx two distal interphalangeal joint seven distal phalanx seven. These tumors usually are one to two centimeters in diameter they are either cystic or solid and usually are fixed to the underlying

Figure 124 Giant cell tumor of tendon sheath on dorsal surface of proximal interphalangeal joint of index finger

tissues but may be slightly movable They are non tender and only 20 per cent of the patients complained of any associated pain

In none of our cases did the tumors involve bone but occasionally this may happen Four cases out of forty three have been reported where there was definite bone involvement at operation[21] However in seventeen where x rays were taken bone changes were noted in eight

Treatment is by surgical excision and not by mere shelling out of the tumor The recurrence rate is approximately 12 per cent.[24] The reason for this is the occasional histologic invasion of the capsule These tumors are practically always benign in the fingers but an occasional malignant one with metastasis has been reported from other areas[23]

Although their exact nature is disputed Geschickter and Copeland[25] are strongly of the opinion that these tumors arise from areas where one would expect sesamoid bones to develop They believe that the tumors on the dorsal surface do not show the characteristic microscopic appearance of giant cell tumors and are more properly fibrohemangiomas fibromas or ganglia Galloway *et al*[24] could find no difference in the histology between the dorsal and volar lesions and in the present series there was no histological characteristics which would differentiate the dorsal lesions from the volar lesions

VESSELS

Glomus tumors arise from the glomus—a normal end organ consisting of an arteriovenous anastomosis containing smooth muscle cells and large clear cells known as epithelioid or glomus cells The glomus controls arteriovenous circulation within the fingers and extremities and the temperature of the body These organs are distributed widely over the body The tumors consisting of small purplish red lesions and characterized by excruciating pain occur most frequently in the nail bed and fingertips They occur less frequently on the volar aspects of the first second and third phalanges of the upper and lower extremities. The tumors usually are very small being a few millimeters in

diameter and if not visible may be picked up by the pin test.[27] However they have been reported up to three or four centimeters in diameter.[23,29] Microscopically there are sheets of epitheliod or glomus cells around endothelial lined vessels (Fig 125) Silver staining will demonstrate non myelinated neurofibrils

The subungual glomus tumors the most common variety may erode the bone of the underlying phalanx.[30,33] In addition to excruciating pain which may radiate up the arm there is often evidence of increased perspiration and vasomotor disturbance in the involved extremity [34]

Treatment is surgical excision and recurrences following surgery have not been reported.

Stout and Murray[35] report an unusual type of tumor called a *hemangiopericytoma* They performed tissue cultures of glomus tumors and found that the pericyte a pericapillary cell common to most vertebrates was capable of passing over gradually through transitional forms into smooth muscle fibers [36] They

Figure 125 Glomus tumor Sheets of glomus cells clustered around endothelial lined vessels. (170x)

considered the pericyte to be identical to the epithelioid cell of the glomus. A similar hemangiopericytoma occurred in the left palm of a forty-nine year old man.[37]

Colden *et al.*[38] report the case of a thirty-one year old Italian female who had a painful wrist of several years duration resulting from an immobile extremely tender three millimeter lesion on the dorsum of the right wrist. This tumor was removed and microscopic examination revealed it to be a vascular leiomyoma. These authors believe that this may have originated in the pericyte which is almost universally distributed throughout the body and would account for such tumors and tissues where normal glomus bodies are not found. A similar report appears of a leiomyoma of the flexor tendons of the hand.[39]

Hemangiomas consist of several varieties: capillary (port wine stain), venous (strawberry mark) and cavernous.[40] The latter may occasionally thrombose, become organized and resemble solid tumors (Fig. 126). If the port wine stains are of sufficient size they are removed by surgical excision and skin grafting. X-ray treatment is particularly disappointing and may lead to a more serious deformity of the skin than would otherwise be encountered. The other two types of hemangioma are also better suited for excision and plastic repair.

Figure 126. Firm, non tender movable mass at base of ring finger which proved to be an organizing thrombosed cavernous hemangioma.

diameter and if not visible may be picked up by the pin test.[27] However they have been reported up to three or four centimeters in diameter[28,29] Microscopically there are sheets of epitheliod or glomus cells around endothelial lined vessels (Fig 125) Silver staining will demonstrate non myelinated neurofibrils.

The subungual glomus tumors the most common variety may erode the bone of the underlying phalanx.[30,33] In addition to excruciating pain which may radiate up the arm there is often evidence of increased perspiration and vasomotor disturbance in the involved extremity[34]

Treatment is surgical excision and recurrences following surgery have not been reported.

Stout and Murray[35] report an unusual type of tumor called a *hemangiopericytoma*. They performed tissue cultures of glomus tumors and found that the pericyte a pericapillary cell common to most vertebrates was capable of passing over gradually through transitional forms into smooth muscle fibers [36] They

Figure 125 Glomus tumor Sheets of glomus cells clustered around endothelial lined vessels. (170x)

darkens to a bluish red hue In time multiple tumors occur in adjacent areas and eventually coalesce as bluish black plaques Eventually lymphadenopathy occurs and the tumors appear in the sub-mucosa of the gastrointestinal tract and lungs with death resulting from progressive cachexia intercurrent infection or hemorrhage Histologically the lesions look like cavernous or capillary hemangiomas but gradually their structure becomes indistinguishable from that of a fibrosarcoma Due to repeated hemorrhage there is staining with old blood pigment In a series of thirty-six cases of Kaposi s sarcoma the upper extremity was found to be involved in fourteen per cent [45] The five year survival rate of patients free from disease was 19 per cent The disease appears to occur most often in Jews and Italians and to have originated in the countries of Eastern Europe such as Russia Poland and Italy When the disease involves the extremities it appears to do so in a stocking or glove fashion with subsequent extension to the trunk The average survival interval with treat ment is approximately eight years Treatment consists of surgical excision unless the tumors are too extensive or there is edema which indicates deep vessel involvement. These tumors are rela tively radiosensitive and irradiation is the choice of therapy if surgery cannot be done

Congenital arteriovenous fistulas usually consist of multiple tiny communications between the arteries and veins and are manifested by increased vascularity in the hand with an extensive blood vessel pattern on the hand or forearm depending upon where they lie The involved digit or extremity may be hyper trophied [46] The usual systemic signs of cardiac enlargement, increased pulse rate decreased blood pressure and increased blood volume are not seen However a typical thrill or murmur may be heard in some cases The oxygen saturation of blood in the veins of the involved extremity should be increased over that of the normal limb Treatment of these fistulas is extremely diffi cult and many surgical operations will be necessary A complete cure is seldom obtained Since many of these communications lie in bone bleeding may be profuse and occasionally resection of a bone may be necessary to control the bleeding [47]

When these lesions occur in children there is great danger in the use of x ray since this may destroy the epiphyseal growth lines and lead to disturbed bone formation [41] In deep heman giomas which infiltrate all the tissues of the forearm and hand surgery is extremely difficult and the recurrence rate is quite high Subsequent x ray therapy may be used in these lesions to control recurrences This procedure has been reversed in an attempt to prevent amputation of an arm because of a rapidly growing arterial hemangioma [42] This was first controlled with external roentgen therapy and when the growth of the heman gioma ceased, the covering of the entire arm was removed Follow ing this the arm was re surfaced to prevent radiodermatitis

The use of multiple suture obliteration is advocated in some cases where chromic catgut sutures are placed through the skin into the large channels Each suture is tied on the surface and a pressure fixation dressing applied for several days This is done to collapse the dilated venous channels and to promote obliteration by the inflammation of the catgut. This is to be fol lowed by surgical resection and repair

Occasionally such tumors may be so severe as to require amputation of an arm Hurwitt and Johnston [43] report such a severe case that an interscapulothoracic amputation was necessary Sometimes a hemangioma may be isolated in an individual muscle belly For instance Harrison [44] reports the case of a four teen year old girl with a flexion deformity of the ring finger and swelling of the palm X rays demonstrated round calcium deposits in the region of the mass At operation a lobulated red dark tumor was found extending from the superficial palmar arch to the base of the ring finger infiltrating the tendon of the flexor sublimis

Angiosarcomas consist of solitary firm bulky tumors situated deep in the soft tissues infiltrating muscle fat and veins These are very serious lesions and McCarthy and Pack [45] find that 45 per cent develop lymph node metastasis and the five year cure rate is only 9 per cent Radical excision or amputation is the only curative therapy for angiosarcomas of the extremities

Kaposi's sarcoma is an interesting tumor that originates in the skin as a reddened macule which increases in size The color

is excision of bone with replacement by a bone graft if necessary

Fibrous dysplasia is a disease of the bone giving rise to an area of rarefaction with expansion of the bone and thinning of the cortex Microscopic examination reveals connective tissue and scattered multinuclear cells with lipoid filled macrophages The giant cells differ from those in the giant cell tumor in that the nuclei range from two to ten rather than 15 to 200 Although it usually occurs in the epiphyses of the long bones it has been reported in the metacarpal[80] Treatment is either by curretage and packing with chips or by excision of bone and replacement with a bone graft[81]

Eosinophilic granulomas are bone lesions which rarely involve the hand Loehr[82] reports a case of a twenty two year old male who had three involved areas in the right hand the distal phalanx of the third finger the distal portion of the third meta carpal and the distal portion of the radius

Osteoid osteomas are bone lesions characterized by pain and a definite x ray appearance consisting of a radiolucent central nidus with surrounding osteosclerosis[83] Their true nature is controversial since they have many of the elements of inflam mation and neoplasm They can occur in the finger Carroll[84] reported six cases of osteoid osteoma in the hand and collected twenty two from the literature They were all cured by surgical excision Sevitt and Horn[85] report another case of a fifteen year old girl where the lesion appeared in the distal phalanx of the fifth finger

Osteogenic sarcoma is rarely seen in the hand Clark[86] re viewed the literature and reported the sixth such tumor of the phalanges

Enchondromas are the most common tumors of the hand A review of thirty of these revealed twenty five in the phalanges and fifteen in the metacarpals[87] Pain was found to be present in 26 per cent of the cases and was always associated with pathologic fracture The remainder of the patients were hospitalized because of swelling of the finger or metacarpal bone Five of these tumors were multiple X rays show a typical bone cyst with a small rounded area of decreased density in the center of the bone

BONES

Giant cell tumors of bone are rarely seen in the hand, but when they are they may occur in the metacarpals A giant cell tumor of the first metacarpal with marked expansion of the bone and cortical destruction has been reported[48] Daland[57] describes such a tumor of the third metacarpal bone where the shaft of the bone seems to project into the tumor mass with a saucer shaped depression in the shaft proximal to the lesion Rarely they occur in the phalanges (Fig 127) Usual treatment

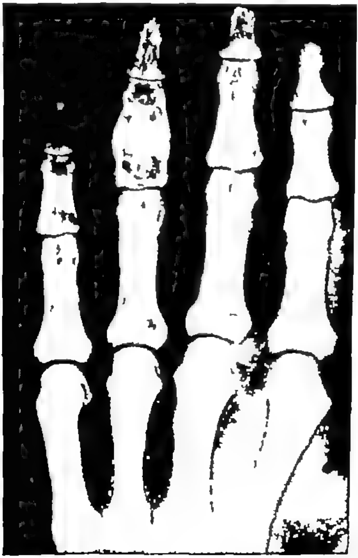


Figure 127 Giant cell tumor middle phalanx ring finger

by amputation An interesting case of a chondrosarcoma was seen recently which apparently arose in a pre-existing ecchondroma that had been present for years before it started to grow larger (Fig 129)

Pyogenic granulomas consist of friable granulation tissue and often resemble tumors (Fig 130) They occur at the site of wounds and incisions Treatment is by excision or cautery

MISCELLANEOUS

Metastatic tumors which involve the hand are extremely rare Bell and Mason[89] reviewed the literature and found detailed case reports of only twelve such cases and added two of their own The majority develop from carcinoma of the lungs and rarely from bladder carcinoma chorionepithelioma of the testicle and miscellaneous tumors. These lesions are always osteolytic and it is of interest that they usually are diagnosed at first as a felon or paronychia.

Neurilemomas are primary tumors of peripheral nerves

Figure 129 Chondrosarcoma arising from a pre-existing ecchondroma of the greater multangular bone

The cortex is expanded and thinner than normal (Fig 128) It often appears in the center of the shaft. Treatment consists of subperiosteal excision of the involved area

Ecchondroma or *exostoses* occur with equal frequency on the phalanges and metacarpals at the insertion of a tendon usually on the proximal side X ray will show the exostoses appearing at one end of a bone Treatment is by surgical excision

Chondrosarcomas are rare tumors in the hand. Of interest in this connection is the recent distinction made by Coley and Higinbotham [88] relative to primary and secondary chondrosar coma. They believe primary sarcomas develop without the inter vention of a benign phase and are similar to osteogenic sarcomas On the other hand, they find that there is a secondary chondrosarcoma which has arisen in a previous benign lesion such as an enchondroma or ecchondroma In a series of these cases, these authors report one of a metacarpal bone Secondary chondrosarcomas have a better prognosis than the others in that they could report a 37 per cent five year survival out of thirty two treated

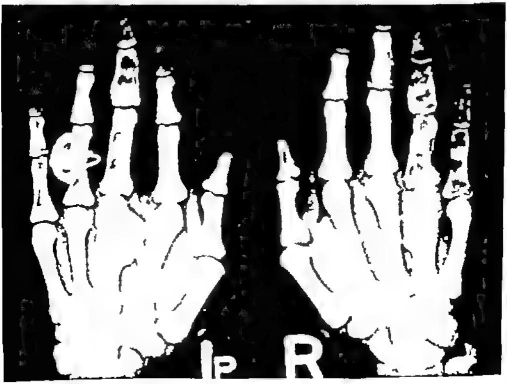


Figure 128. Multiple enchondromata.

Hamartomas are tumor like malformations of congenital origin composed of an abnormal mixture of the elements which normally form the organ in which these tumors originate. A report has been made of a case of a hamartoma in the right palm of a sixty nine year old woman which extended into the web between the long and ring fingers and bulged on the dorsum of the hand between the metacarpal bones [22] X ray revealed a soft tissue mass and calcification in several areas. It was removed by surgery and microscopic examination disclosed a mixture of cartilage, fat and precartilaginous connective tissue in which were scattered foci of osseous metaplasia.

Figure 131 Malignant neurilemmoma radial nerve upper third of left arm.

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which occasionally occur in the hand and usually arise from small nerve branches which can be sacrificed with impunity Rarely they arise from the major nerve trunks and present a problem in treatment (Fig 131) When they possess a definite capsule (benign encapsulated neurilemoma) they may be shelled out leaving the nerve intact. When they infiltrate the nerve bundles (plexiform neurilemoma) or when biopsy shows a malignant change (malignant neurilemoma) a more aggressive approach is necessary with excision of the involved nerve Frozen sections of the resected ends should be performed since these tumors tend to grow along the nerves The nerve should then be repaired according to the principles discussed in Chapter 9 If the nerve ends cannot be approximated or if the anticipated nerve recovery will take a long time suitable tendon transfers should be done Very rarely these tumors have occurred in bone [60]

Cammermeyer [61] describes a small tumor on the finger of a fifty year old man which seemed to arise from a tactile end organ

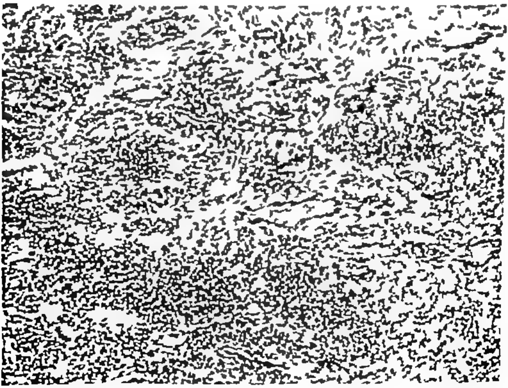

Figure 130 Pyogenic granuloma. Microscopic section showing vascular granulation tissue. (100x)

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CHAPTER 15

CONGENITAL DISORDERS

Congenital deformities consist of absence fusion multiplicity and altered growth pattern of parts[1,2]

ABSENCE OF PARTS

Paraxial hemimelia is a condition where one side of the distal part of the extremity is absent When the defect affects the radial bud (*radial hemimelia*) there is absence of all or part of the radius the radial bones of the carpus (navicular greater multangular) first metacarpal and often the thumb and adjoining finger together with defects in the soft tissues along the radial side of the forearm The ulna is short and thick and as the hand grows it deviates toward the radial side of the palm until it is often at a right angle to the forearm[3-5] Such defects frequently are associated with other anomalies so severe that the individual does not survive. These defects are treated with proper splinting during growth to correct the deformity with subsequent excision of the contracted parts and fusion of the hand in correct alignment.[6] The possibility of pollicization of such a hand must be taken into account.

A defect of the ulnar bud (*ulnar hemimelia*) which is less frequent than radial may produce absence of part or all of the ulna, pisiform hamate associated metacarpals and digits Defects in the soft tissues on the ulnar side of the arm may take place Since the radius is the most important bone in the wrist the hand dysfunction is not as severe as with the opposite defect Treatment is instituted according to the principles outlined for radial hemimelia

Paraxial hemimelia may occur only in the soft tissues[7,8] Several authors report cases in which the extensor pollicis brevis is absent bilaterally with the resultant deformity of the first meta

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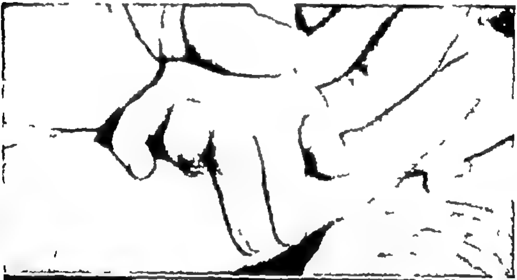
occur anywhere in the upper extremity involving the entire extremity (*amelia*), forearm (*hemimelia*), the hand (*acheiria*) and fingers (*adactylia*)[1–13] (Figs. 133 and 134). The amputations may be incomplete and present congenital annular grooves. They may be superficial and involve only skin and subcutaneous tissue or deep involving fascia, tendons and bones. Usually they are combined with some other anomaly such as syndactylism and brachydactylism. Such conditions often are called pseudo-*ainhum*.[14-17] Treatment when indicated consists of excising the circular bands and re-approximating the subcutaneous tissue and



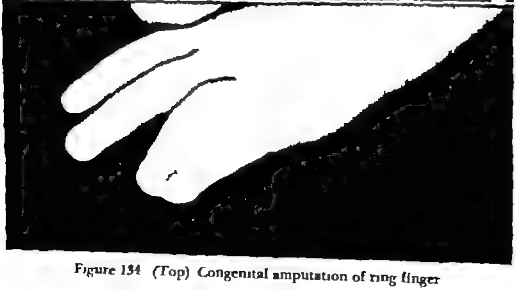


Figure 134. (Top) Congenital amputation of ring finger.

Figure 135. (Bottom) Syndactylism, fourth and fifth fingers.

carpal bone held in adduction and the proximal phalanx flexed forward and partially subluxed [9,10] There also is ulnar deviation of the hand. These cases are repaired by transfer of the common extensor tendon of the index finger to the dorso-lateral surface of the proximal phalanx of the thumb Occasionally the defect may include only the thenar eminence

Cleft hand is a rare anomaly in which there is a defect of the central portion of the hand (Fig 152) A V-shaped cleft, which tapers proximally divides the hand into two parts, the digits in each part being webbed Usually the middle metacarpal is missing Treatment as follows may benefit the patient if the cleft is too wide its function may be improved by narrowing if the hand functions with a "pincer like" movement it is more important to keep this movement rather than to attempt to improve the appearance This condition is usually a Mendelian dominant and never appears in a child unless present in a parent.[11]

Amputations and annular grooves Congenital amputations may

Fig 152

Fig. 153

Figure 152. X ray of cleft hand showing extreme case with loss of metacarpals and phalanges of second, third and fourth fingers.

Figure 153. Congenital amputation involving phalanges and part of metacarpals.

occur anywhere in the upper extremity involving the entire extremity (*amelia*), forearm (*hemimelia*) the hand (*acheiria*) and fingers (*adactylia*)[12,13] (Figs 153 and 154) The amputations may be incomplete and present congenital annular grooves They may be superficial and involve only skin and subcutaneous tissue or deep involving fascia tendons and bones Usually they are combined with some other anomaly such as syndactylism and brachydactylism Such conditions often are called *pseudoainhum*[14,17] Treatment when indicated consists of excising the circular bands and re-approximating the subcutaneous tissue and

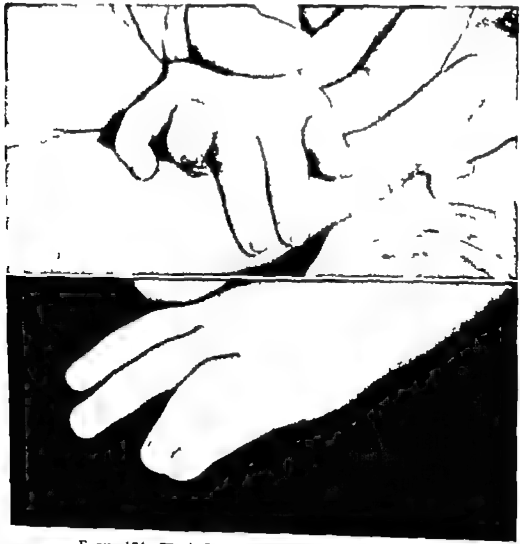


Figure 154 (Top) Congenital amputation of ring finger

Figure 155 (Bottom) Syndactylism, fourth and fifth fingers.

carpal bone held in adduction and the proximal phalanx flexed forward and partially subluxed [9,10] There also is ulnar deviation of the hand These cases are repaired by transfer of the common extensor tendon of the index finger to the dorso-lateral surface of the proximal phalanx of the thumb Occasionally the defect may include only the thenar eminence [7]

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Amputations and annular grooves Congenital amputations may

Fig 132

Fig 133

Figure 132 X ray of cleft hand showing extreme case with loss of meta carpals and phalanges of second, third and fourth fingers.

Figure 133 Congenital amputation involving phalanges and part of metacarpals.

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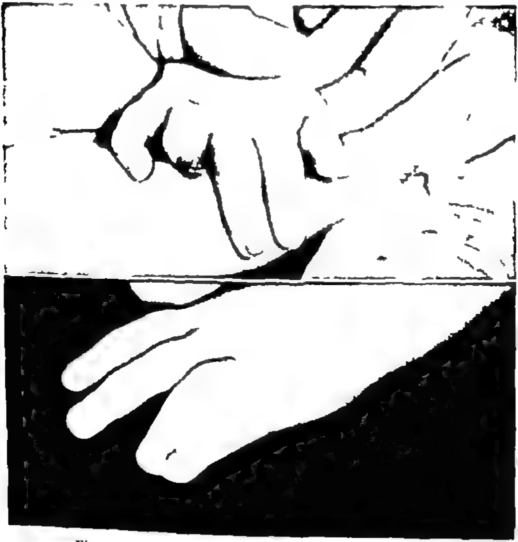

Figure 134 (Top) Congenital amputation of ring finger

Figure 135 (Bottom) Syndactylism, fourth and fifth fingers.

skin To prevent recurrence of the constriction, the skin incision is made so that a circular scar does not occur This may be done by making alternate diagonal cuts on either skin margin down to the deep fascia thus performing a modified Z plasty One should not encircle the finger completely at the same operation but should do only half a finger at a time.

FUSION OF PARTS

Syndactylism Web fingers and toes have been noted for centuries (Fig 135) A very clear description has been written by Ambroise Pare [18]

"There is also another disease in fingers for they sometimes stick together and otherwhiles they are verie little separated If by chance they shall grow together by a little thin skin and flesh they shall forthwith bee divided with a sharp razor but if they bee joined by the interposition of a more gross and dens substance, to wit the nerves, tendons and vessels being knit together on each side, it will be best not to meddle at all with the dividing them.

Numerous case reports have appeared, and Bell [19] was able to investigate material including 700 cases of the digital anomaly and sixty three pedigrees.

When this disease occurs in the fingers the middle and ring fingers are most commonly involved. Although males are supposed to be affected more than females this does not appear to be true in Bell s series There may be merely a thin web of skin between the fingers or actual fusion of bone, nerves and fingers. This condition may be associated with a special type of polydactylism wherein a duplicated fourth finger lies in the webbing between the third and fourth fingers [19] Other associated defects have been reported [20]

The optimum time of operation is about three years of age unless the webbing is altering the growth of the bone. A classic operation is the one first suggested by Zeller (1810) where the fingers are cut apart and a V-shaped flap made on the web space of the dorsal and palmar surfaces The two flaps are sutured side by side thus developing an adequate web space. The sides

of the fingers are covered with a skin graft which should cover the web and extend onto the dorsal and palmar surfaces

Oldfield[21] has developed a procedure which appears to be a more successful operation for the prevention of adduction contraction between the fingers A horseshoe or U flap is raised from the dorsum of the fused fingers with the base of the flap corresponding to the level of the dorsal web and the flap extending distally as far as the first interphalangeal joint From the remaining skin of the syndactyly two flaps are raised to cover the side of the more important finger This incision begins at the distal extremity of the web flap incision and continues along the dorsal surface of the middle finger It then passes abruptly forward over the end of the finger toward the palmar surface and continues along the palmar aspect and radial side of the middle finger as far as the normal palmar web line These incisions are deepened to free the lateral flaps and the fused fingers are separated If there is bony fusion a saw is used If the nails are fused a scapel is used for division The flaps are sutured in position and any raw areas covered with a split thickness skin graft. A pressure dressing is applied for ten days followed by removal of sutures and institution of active motion

If more than two fingers are fused Barsky[*] recommends cautiousness when separating both sides of the digit It probably is safer to operate on one side of the finger at a time If the tendons are united they should be left attached to the better finger and a tendon graft performed on the opposite finger

Symphalangism is a fusion of the interphalangeal joints where the middle phalanx usually is fused to either the proximal or distal phalanx Dr Harvey Cushing named this condition "Symphalangism following a study of a large family that originally came from Scotland and settled in Virginia (1700) In this particular family the deformity was transmitted through seven generations with 25 per cent of 302 individuals affected The trait appears to behave as a simple Mendelian dominant[22] If an operation is deemed advisable an arthrodesis of the joint in the position of function is probably all that can be offered such a patient

Synostosis Fusion of other bones of the upper extremity may

skin To prevent recurrence of the constriction the skin incision is made so that a circular scar does not occur This may be done by making alternate diagonal cuts on either skin margin down to the deep fascia thus performing a modified Z-plasty One should not encircle the finger completely at the same operation but should do only half a finger at a time

FUSION OF PARTS

Syndactylism Web fingers and toes have been noted for centuries (Fig 135) A very clear description has been written by Ambroise Pare [18]

"There is also another disease in fingers for they sometimes stick together and otherwhiles they are verie little separated If by chance they shall grow together by a little thin skin and flesh they shall forthwith bee divided with a sharp razor but if they bee joined by the interposition of a more gross and dens substance to wit the nerves tendons and vessels being knit together on each side it will be best not to meddle at all with the dividing them

Numerous case reports have appeared and Bell [19] was able to investigate material including 700 cases of the digital anomaly and sixty three pedigrees

When this disease occurs in the fingers the middle and ring fingers are most commonly involved Although males are supposed to be affected more than females, this does not appear to be true in Bell's series There may be merely a thin web of skin between the fingers or actual fusion of bone nerves and fingers This condition may be associated with a special type of polydactylism wherein a duplicated fourth finger lies in the webbing between the third and fourth fingers [19] Other associated defects have been reported [20]

The optimum time of operation is about three years of age unless the webbing is altering the growth of the bone A classic operation is the one first suggested by Zeller (1810) where the fingers are cut apart and a V-shaped flap made on the web space of the dorsal and palmar surfaces. The two flaps are sutured side by side thus developing an adequate web space The sides

of the fingers are covered with a skin graft which should cover the web and extend onto the dorsal and palmar surfaces

Oldfield [1] has developed a procedure which appears to be a more successful operation for the prevention of adduction contraction between the fingers A horse-shoe or U flap is raised from the dorsum of the fused fingers with the base of the flap corresponding to the level of the dorsal web and the flap extending distally as far as the first interphalangeal joint From the remaining skin of the syndactyly two flaps are raised to cover the side of the more important finger This incision begins at the distal extremity of the web flap incision and continues along the dorsal surface of the middle finger It then passes abruptly forward over the end of the finger toward the palmar surface and continues along the palmar aspect and radial side of the middle finger as far as the normal palmar web line These incisions are deepened to free the lateral flaps and the fused fingers are separated If there is bony fusion a saw is used If the nails are fused a scapel is used for division The flaps are sutured in position and any raw areas covered with a split thickness skin graft. A pressure dressing is applied for ten days followed by removal of sutures and institution of active motion

If more than two fingers are fused Barsky [2] recommends cautiousness when separating both sides of the digit. It probably is safer to operate on one side of the finger at a time If the tendons are united they should be left attached to the better finger and a tendon graft performed on the opposite finger

Symphalangism is a fusion of the interphalangeal joints where the middle phalanx usually is fused to either the proximal or distal phalanx. Dr Harvey Cushing named this condition Symphalangism following a study of a large family that originally came from Scotland and settled in Virginia (1700) In this particular family the deformity was transmitted through seven generations with 25 per cent of 302 individuals affected The trait appears to behave as a simple Mendelian dominant.[22] If an operation is deemed advisable an arthrodesis of the joint in the position of function is probably all that can be offered such a patient.

Synostosis Fusion of other bones of the upper extremity may

occur and are most frequently found to occur in the carpal region. Practically every conceivable combination of carpal fusion has been reported, but the most common appears to be the lunate triquetral fusion which O Rahilly[23] found present in 0 13 per cent of 743 wrists This is most common in some of the African races[24,25]

MULTIPLICITY OF PARTS

Polydactylism is a deformity which demonstrates an abnormal number of fingers Usually the extra digit is along side of the thumb or little finger (Figs 136 and 137) Bifid thumbs are *a minor variant of this congenital defect* (Fig 138) Treatment consists of excision of the extra digit for cosmetic reasons Handforth[26] found that polydactylism was quite high among Chinese prisoners (2 4/1000) with the most common abnormality being a duplication of the first digit. A rarer type of polydactylism is a duplication of the fourth digit in the web of a syndactylism between the third and fourth digits Even more bizarre are the

Fig 136

Fig 137

Figure 136 Polydactylism. Extra digit alongside thumb

Figure 137 Polydactylism. Extra digit alongside fifth finger

polydactylies associated with *dimelia* (where a limb or major part of the limb is duplicated) In these cases the fingers usually are doubled and show mirror imaging O Rahilly[8] had a case where there was no thumb or radius but a doubling of the second to the fifth fingers with mirror imaging There was also duplication of the hamate and capitate with two ulnar bones and no radius This condition can result in extreme cases of polydactyly the number of recorded fingers going all the way to forty

Hyperphalangism consists of an excessive number of phalanges the thumb being most commonly involved with three phalanges Grobelnik[27] reports a case and believes that this deformity adds fuel to the argument as to whether the normal thumb consists of three phalanges without a metacarpal or one metacarpal and two phalanges Since the metacarpal of the thumb has an epiphysis at its proximal rather than distal portion some people

Figure 138 Bifid thumb

feel that this is a phalanx and not a metacarpal In Grobelnik's case the metacarpal had an epiphysis on both ends. The patient had difficulty using his hand because opposition was hindered and the fist was poor He treated this by removing the middle phalanx and placing the thumb in plaster-of Paris for six weeks after which physiotherapy was instituted Another case of a triphalangeal thumb is reported by Sallam[28]

Accessory bones Apart from the sesamoid bones which were discussed in the section on anatomy there are numerous accessory bones present in the carpus *Os centrale*—a dorsal ossicle between the navicular capitate and lesser multangular *Os epitriquetrum*—at the dorsal distal radial angle of the triquetrum in the medial intercarpal space between the lunate triquetrum and hamate *Os hypotriquetrum*—in the same space but on the palmar aspect *Os styloideum*—a dorsal ossicle between the lesser multangular capitate and the second and third metacarpals *Os triangulare*—between the distal end of the radius ulnar styloid process lunate and triquetrum *Os vesalianum*—an ossicle between the hamate and fifth metacarpal[23]

A bipartate scaphoid rarely may occur and be confused with a fracture The surfaces should have smooth regular edges with clear joint space and show no arthritic changes The density should be normal and there should be no avascular necrosis

ALTERED GROWTH OF PARTS

Congenital flexion contracture of fingers usually involves the fifth finger It is one of the most frequent of the inherited digital anomalies[29,30] *Camptodactyly* a flexion of any of the fingers, is a term often used in referring to this condition However the appropriate term should be *streblomicrodactyly* designating only flexion in the little finger In other words this is a special form of camptodactyly The condition usually is bilateral and symmetrical It is characterized by a flexed position of the proximal interphalangeal joint of the fifth finger and occasionally the fourth finger It is present at birth remains static until the tenth year of life when flexion may progress and become arrested to recommence at the age of sixteen or eighteen There may be hyperextension of the metacarpophalangal joint Surgical

treatment is very disappointing since all the tissues become involved in the contracture and it tends to recur after their excision[1] Rarely this condition may affect all four fingers of the hand[21]

Figure 189 Hypertrophy of index finger

Brachydactylism is a deformity wherein some of the phalanges or metacarpals are short or absent. Like most such general conditions it is a definite inherited trait.[23] Shoul and Ritvo[23] report an interesting series of three cases of brachydactylism in which the involved fingers had four phalanges

Megalodactylism consists of hypertrophy of the digits (Fig 139) A certain percentage of these cases may be due to an over

growth of peripheral nerves and also may result from hemangiomas or lymphangiectasia[34-36] Megalodactylism is seldom benefited by surgery

Madelung's deformity occurs when the growth of the radius falls behind that of the ulna producing a volar and ulnar curve The normal growth of the ulna makes this bone luxate from the radius and project dorsally and distally giving a clinical impression of a forward dislocation of the wrist. There is also limitation of motion of the wrist. The carpal bones become wedged between the deformed radius and displaced ulna presenting a pyramidal appearance with the lunate at the apex. The disease usually occurs in adolescence and is four times as frequent in women as men[37]

Treatment is deferred until bone growth is complete A wedge osteotomy is performed and the head of the ulna removed A sling is placed around the distal ulna to prevent its dislocation and the hand and forearm immobilized in plaster in an over corrected position

Other growth disorders can occur such as severe ulnar abduction of the fingers due to a congenital shortening of the collateral ligaments a characteristic radial deviation of the terminal phalanx of the fifth finger and a prominence at the base of the first metacarpal giving rise to a step sign[38-40]

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CHAPTER 16

VASCULAR DISEASES

TRAUMA

Penetrating trauma of the upper extremity may involve the vascular tree causing spasm, contusion or laceration. These injuries are serious as evidenced from World War II statistics.[1] Gangrene requiring amputation occurred in 43 per cent of axillary artery injuries and in 28.6 per cent of subclavian injuries. Gangrene following brachial artery injury depended upon whether or not the profunda branch was intact. Injuries above the profunda resulted in a 55 per cent amputation rate and below it in a 25.8 per cent rate. Modern advances in repair of blood vessels and the use of venous and arterial grafts have done much to decrease the incidence of gangrene. Numerous surgeons in the Korean War reported on vascular injuries and found that the incidence of gangrene in upper extremity injuries was extremely low.[2-4]

When there is evidence of an arterial injury manifested by a large hematoma at the site of injury or absence of distal pulsation, the wound should be explored using classical surgical incisions and if possible not going through the initial wound. Proximal and distal control of the vessel is secured and as an aid to this a proximal tourniquet may be valuable. The arterial wounds are debrided to be sure that all injured artery is removed. If there is a partial laceration it may be repaired in a longitudinal or a transverse manner. However, in severe lacerations where such repair would greatly constrict the artery, and in complete severances, the damaged artery is cut across at right angles and an end-to-end suture performed. Since there is evidence that high velocity missiles damage the artery farther than is visible, Jahnke[3] advocates that a centimeter of lacerated artery be removed from each end. The adventitia is stripped from the artery proximally

and distally for several inches When necessary collateral branches are divided to permit mobilization of the blood vessel and partial flexion of extremities may be utilized to permit suture without tension An oiled 00000 silk suture is used for the arterial repair It is important that the anastomosis be covered with muscle or fascia at the completion of the procedure. In instances where the laceration is so extensive that the ends cannot be brought together without undue tension a vein or arterial graft will be necessary The wound is closed either primarily or secondarily depending on its condition

Thrombosed segments of artery should be excised and an end to-end suture or a graft used to repair the defect. Spasm in an artery may be relaxed by using topical papaverine

Non-penetrating trauma may result in thrombosis or spasm in an artery This is most commonly seen in the early stages of Volkmann s contracture which will be discussed in another chapter

Relatively minor trauma also may result in damage to blood vessels of the hand. Mansfield,[7] reports the traumatic thrombosis of an ulnar artery in the palm of an engineer who used the palms of his hands to hammer on a chain case during the course of his work. He developed tenderness over the base of the hypothenar eminence and a cord like structure could be felt which on exploration proved to be a thrombosed ulnar artery which was excised An even more indirect trauma was reported occurring in a seventy year old dentist who complained of severe pain in his right hand[8] One week before hospital admission he noticed the onset of tingling, cold pain and cyanosis at the tip of the third finger and within forty-eight hours in the fourth and fifth fingers The tips of the third fourth and fifth fingers were cyanotic with small areas of demarcating gangrene These fingers were also cold and tender and the radial and ulnar arteries were palpable The ulnar artery was exposed and found to be com pressed and contused by the volar carpal ligament When this was incised and the wall of the artery injected with procaine the pulsation passed into the distal segment Immediately after operation the pain was relieved with no recurrence This is akin to the median nerve compression in the carpal tunnel syndrome.

Gangrene of the forearm and hand have followed the use of the radial artery for intra-arterial transfusion[9,10] There was normal communication between the ulnar and radial arteries in the hand Vasospasm of the blood vessels produced by the use of cold blood may have been a responsible factor with an added factor being the perfusion of the extremity with unoxygenated blood When performing an arterial transfusion these authors recommend limiting the transfusion to a period of one hour and using whole warm blood

Traumatic aneurysms may occur in the hand and have been ably reviewed by Middleton[11] In *false aneurysms* there is a destruction of the blood vessel wall with formation of hematoma which becomes the retaining sac of the aneurysm This sac be comes lined with endothelium and muscle elements are absent from the wall These most commonly follow puncture wounds of the hand. In Middleton s review of seventy aneurysms of the palm fifty four were of this false variety The *true* aneurysm is due to a weakening of the arterial wall but muscle elements usually can be identified on microscopic examination In Middleton s series sixteen were of this variety and the majority were due to non-penetrating trauma with a few due to bacterial endocarditis They may rarely arise spontaneously These aneurysms may fol low a single severe contusion or numerous minor contusions. The latter often are called Occupational Aneurysms Excision gives excellent results Their cure is simple since there is excellent collateral circulation in the hand Since Middleton s review many isolated case reports have appeared[12,14] In a five year study at the Boston City Hospital Nabseth[15] found three false aneurysms

Traumatic A V fistulas of the hand are rare civilian injuries Nabseth[15] found two in a five year survey at the Boston City Hospital Such fistulas have a small diameter and are a long distance from the heart and do not produce the serious circu latory problem of fistulas in other locations i e increased pulse pressure heart rate and blood volume with subsequent cardiac failure They usually present as small pulsating masses with dilated adjacent veins A bruit may be heard and the oxygen content of the involved veins is higher than the normal veins Simple excision cures these lesions

Figure 140 (Top) Gangrene of skin at tip of plastic catheter used for levophed infusion.

Figure 141 (Bottom) Gangrene of finger following digital nerve block with novocain and epinephrine

CHEMICAL GANGRENE

Deliberate arterial injection of gentian violet ether[15] and even blood[9,16] has resulted in gangrene of the hand Occasionally arteries are mistakenly injected instead of veins especially when a superficial cubital radial or ulnar artery is present[17] Gangrene has occurred following such injections of pentathol curare quinine heavy metals and antibiotics Nach and Lohman[18] reported gangrene of the hand following injection of an artery with codeine by a narcotic addict In this case the injected drug produced a thrombosis of the radial and ulnar artery

Intravenous medication rarely produces gangrene but local areas may develop at the site of levophed infusions They may occur at the site of venipuncture or at the tip of a plastic catheter introduced proximally in the arm (Fig 140)

General medicinal agents occasionally may produce gangrene The best known of these are ergot preparations In recent years the use of ergotamine tartrate for relief of pruritis has come into vogue and resulted in several cases of gangrene of the fingers and lower extremity[19-21] Wells and Anderson[22] investigated the mechanism of increased susceptibility to ergot and found that in rats it was produced by thyroxin and liver damage. They reason that throxin possibly may interfere with the elimination or destruction of the alkaloid and that liver damage may interfere with the elimination of the ergot alkaloids thus predisposing to ergot gangrene They note that ergot gangrene is most often associated with thyrotoxicosis and jaundice but almost never following the use of these alkaloids in the treatment of migraine

Lindstrom[23] reports a fulminating occlusive arterial disease resulting in gangrene of the extremities following anti syphilitic treatment with neoarsphenamine. Histologic examination revealed a panarteritic process characterized by a fibrinoid medial necrosis, hyperplasia of the subintimal tissue and infiltration by granulocytes and eosinophiles

Topical applications of chemicals occasionally may result in gangrene as evidenced by the high incidence of gangrene which followed the phenol dressings of the past generation

Digital nerve block sometimes may result in gangrene of a

finger and the author has seen nine such cases (Fig 141) Usually this is due to epinephrine in the novocain solution but secondary factors such as the use of a tourniquet and an increased quantity of injected fluid may play a role[24] When performing a digital nerve block for anesthesia of a finger no more than 1 to 1½ cc. of 1 per cent novocain solution without epinephrine is used and no tourniquet is applied Debeyre and Mattei[25] report two cases following local anesthesia for a felon of a finger in which no adrenaline was used In order to obviate this possible complication of digital gangrene Holmes and Graff,[26] recommend injection of the nerves between the metacarpophalangeal joints rather than along the finger However it has been previously pointed out that gangrene may even follow this type of digital block.[24] Thermal damage may play a role in this gangrene when an anesthetized finger is placed into water of a scalding temperature However even at temperatures below this level with a disturbed circulation secondary to the digital block, the heat may cause damage

COLD GANGRENE

Frostbite occurs when an extremity is exposed to a freezing temperature and the tissues become frozen There are many predisposing conditions—such as temperature environment and length of exposure However there are other factors which control heat loss—such as wind velocity degree of wetness of an extremity and length of immobility Factors conducive to vasospasm—such as chilling, hunger anxiety use of tobacco and trauma—are more subtle aggravations

The affect of freezing temperatures on an extremity is a vasoconstriction which produces blanching associated with numbness If the temperature is sufficient, ice crystals will appear on the tissues but these are not necessarily indicative of future destruction[27] The major source of damage to living cells during freezing is still unknown and probably encompasses some change in cell chemistry Lovelock[28] has shown that the major source of damage may be the deleterious affect of strong salt solutions which are produced during the formation and dissolution of ice Changes in the proportion of lipids and phospholipids in the cell mem

brane may also play a role Although ice formation in the cells may be compatible with recovery of the tissue Smith[27] finds that bending a part frozen in this way inevitably results in lesions of frostbite

After thawing of the member there is an immediate hyperemia as evidenced by skin temperature and fluorescence studies[29] During this period there is an increased permeability of the capillaries and an increased lymph flow from the affected part[30] The damage to the blood vessels may be so severe that blood leaks from them into the tissues Clinically such extremities are red warm and painful Edema occurs giving rise to blistering with large blebs seen within a day or two after thawing There may be such a severe degree of plasma loss from the blood vessels in the extremities that the capillaries are sludged with red blood cells[30,31]

There is evidence that blood flow ceases two to four days following thawing resulting in necrosis of tissue There is a possibility that this tissue change is due to the silting of red cells in the capillaries[31,32] However it also may be true that these changes in the blood vessels are secondary to necrosis Several investigators studied the muscles of extremities exposed to sub-freezing temperatures and found three distinct histologic lesions a coagulation necrosis in the muscle adjacent to the cold an atrophy of the muscle most distant from the cold and a slow necrosis in the intervening muscle[33,34] This layering of the lesions from the surface is difficult to explain on a vascular basis

After the acute phase of the disease is over and the edema has subsided necrosis may occur in about 10 per cent of frost bitten extremities[35,36] Necrosis of tissue may be seen more commonly than this however but it is usually superficial and does not result in loss of a part. Sensory loss may be evident for many weeks following frostbite and on return of sensation pain may recur to gradually subside as the underlying cold induced nerve lesion heals spontaneously Atrophy of skin and underlying muscle together with limitation of joint motion may occur Vasospastic phenomenon and hyperhidrosis may appear in some of the limbs This may be due to the fact that of all the nerve fibers the sympathetic fibers are the most resistent to cold

and are destroyed only by very severe exposure[37] This vasoconstriction was demonstrated by arteriography to be present proximal to the frostbitten area four to five months after the initial injury[38]

A review of x ray bone changes encountered in frostbite revealed 58 per cent of cases to show osteoporosis of a slight degree[35] Bone exposed to necrotic tissue revealed changes secondary to osteomyelitis One group of special significance present in 11 per cent of the series consisted of small round punched-out areas of decreased density which usually opened into joint spaces. These changes did not become noticeable until months after cold exposure When the frostbite occurs in children epiphyseal injury may occur as demonstrated by x ray changes.[36]

Many methods of treatment have been attempted to prevent gangrene and other serious sequelae It has been fairly well proven that sympathectomy in the early stages is of no value[39] Heparinized experimental animals demonstrated as much gangrene as other animals and had a higher death rate than the control group[40] Adrenocorticotrophic hormone (ACTH) has been tried and found wanting[41] There is statistical evidence that the use of dehydrogenated alkaloids decreases the incidence of gangrene in experimental animals because of their vasodilating action[42,43] The most promising lead is that of Shumacker and Kunkler[44] who demonstrate that rapid thawing will result in less gangrene than spontaneous thawing Such rapid thawing probably reduces the exposure time to cold

Until some of the experimental leads have more clinical value it is best to treat frostbite by the prevention of further damage This is done by applying loose sterile dressings administering chemotherapy and refraining from massage or motion of the part A policy of cautious, watchful waiting is undertaken and if necrosis takes place only dead tissue is excised In most cases seen in civilian practice gangrene of a part does not occur and the affected superficial tissues will spontaneously peel away leaving relatively normal tissue underneath The occasional spastic phenomena which may be present in such extremities for months to a year after injury may be relieved by sympathectomy

Exposure to cold temperatures above the freezing level for

varying lengths of time gives rise to the *immersion hand* It has been found that at least two thirds of patients with immersion foot had injury to the hands[45] During exposure the hands are numb cold and clumsy after exposure to normal environment the hands become hot and throbbing and intense paresthesias are present Swelling may occur and when it subsides is wasting of the intrinsic muscles is prominent Hypesthesia and hypalgesia of the fingertips may take place As in frostbite late sequelae may be vasomotor phenomena and hyperhidrosis

OCCLUSIVE DISEASES

Arterial emboli lodge in the upper extremities in a variable percentage of cases In a series of 172 arterial emboli cases reviewed at the Massachusetts General Hospital the upper extremity was involved in 13 9 per cent[46] In a series of 101 peripheral emboli cases reviewed at the Boston City Hospital the upper extremity was involved in only 5 per cent (Fig 142)

The source of arterial embolism is usually a diseased heart

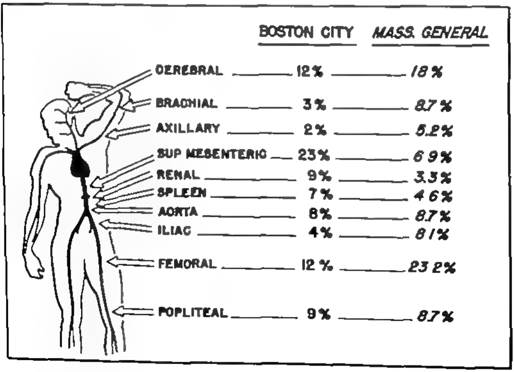

Figure 142. Arterial emboli. Sites of lodgement in 172 cases at Massachusetts General Hospital[46] and 101 cases at Boston City Hospital

with auricular fibrillation In a series of fifty five cases seen at the Boston City Hospital the etiology was arteriosclerotic heart disease twenty-six cases rheumatic disease seventeen hypertensive heart disease four and bacterial endocarditis three In four cases an arteriosclerotic plague of the aorta predisposed to embolism in one there was a patent foramen ovale in which the source of the embolus was phlebitis of the right iliac vein

Upper extremity emboli rarely result in gangrene Conservative therapy should be followed consisting of sympathetic blocks and vasodilating drugs Rarely if there is underlying obliterative vascular disease gangrene may occur (Fig 143)

Figure 143 Gangrene of hand caused by arterial embolus.

Buerger's disease rarely affects the upper extremity A report on a series of 1 400 patients with this disease revealed that only five had major amputations of the upper extremity[47] Another review of 180 cases at the Massachusetts General Hospital demonstrated that only 6 per cent required amputation of the fingers with no amputation above this level necessary[48] Treatment consists of sympathectomy cessation of smoking and control of sepsis with antibiotics

Periarteritis nodosa occasionally may involve a peripheral nerve and produce a peripheral nerve palsy Heathfield and Williams[49] report the case of a median and ulnar nerve lesion in a twenty

seven year old housewife with this disease

Obliterative arteriosclerosis results in gangrene in upper extremities in a very small percentage of cases Treatment is usually conservative.

SPASTIC DISEASE

Raynaud s disease is an arterial spasm usually stimulated by cold or excitement affecting the hands in a great majority of cases occasionally the feet and rarely the nose and ears Approximately 80 per cent of the sufferers are women and it appears in the third and fourth decades of life When the disease affects the hand it is usually bilateral and symmetrical and the most common complaint is sudden pallor of the fingers (Fig 144) As the circulation returns they become cyanotic and then hyperemic

Between attacks the hands may be cold and sweaty Gangrene of the fingertips rarely occurs and when it does it is merely a small

Figure 144 Raynaud s disease exhibited by symmetrical blanching of fingers.

area of necrosis at the tip of the finger Atrophic soft tissue changes might occur in the hand Occasionally a disease process similar to Raynaud s disease may be the forerunner of scleroderma

Treatment is by reassurance and conservative measures such as advice on wearing warm clothing and gloves in cold weather and avoidance of smoking Occasionally vasodilating drugs such as priscoline and roniacol are of value and if the cases are associated with severe anxiety or nervousness some tranquilizing agent such as serpasil has been of benefit. In more severe cases sympathectomy will give relief although it is very difficult to completely denervate the sympathetic nerves in the upper extremity Over the course of five years, Robertson and Smithwick[50] have shown that 35 per cent of upper extremities denervated by either root section or ganglionectomy will have recurrence of vasoconstrictor activity

Reflex vasospasm of the hands may be secondary to many conditions such as cervical ribs scalenus anticus syndrome and trauma Treatment of mild cases is by conservative measures such as mentioned in Raynaud s disease and of severe ones by sympathectomy

An occasional myocardial infarction will develop gangrene of the fingers[51,52] This appears to be a vasospastic condition secondary to a lowered cardiac output.

Nygaard[53] reports a Raynaud s phenomenon secondary to a fracture of the navicular bone aggravated by working When the area of the navicular bone was infiltrated with 1 per cent novocain the Raynaud s phenomenon did not occur Following this the patient had an excision of the scaphoid and postoperatively the Raynaud s syndrome disappeared

The use of pneumatic tools has resulted in a disease entity quite similar to Raynaud s disease which was first reported by Loriga.[54] These patients manifest cold fingers with the typical color changes of Raynaud s disease and rarely they progress to acral gangrene and ulcers

The cause appears to be the vibration of tools at a rate between 2000 and 3000 revolutions per minute With lower rates changes in the bones and joints are more common It has been

estimated that—of 100 men working with such vibrating tools four showed vascular changes in two years with the number rising to 18 per cent in three and to approximately 55 per cent between the fourth and fifth[85] The basic cause of the vascular change is unknown Biopsies on such patients revealed no histologic changes in the blood vessels[86] Obliterative changes have been reported in some of the affected hands by arterio graphic studies Changes have been found in the capillary loops which show a definite decrease in size with small almost occluded vessels[88]

Although the patient may cease work the vasospastic phenomena may continue for years Hoerner[89] reviewed some of the possible preventative measures a few of which might be frequent changing of jobs so that no one is exposed to vibrations for many days in succession the use of mechanical means of holding the tool and object and the use of other than pneumatic or electrical tools to bring about the same operation

INFECTIONS

A massive localized infection in an extremity may result in gangrene. A recent experience is of great interest A fifty seven year old white morphine addict injected heroin into his left arm near the elbow four days before entering the hospital Infection developed and spread to the entire forearm The hand and fingers were cyanotic and no pulse could be felt in the wrist Several incisions were made and creamy pus was obtained which cultured hemolytic streptococcus On hospital admission he was placed on penicillin therapy but the circulation in the arm did not recover (Fig 145) Exploration of the antecubital fossa was performed which revealed the brachial radial and ulnar arteries to be in intense spasm. Saline compresses over these vessels caused some pulsation to return A periadventitial sym pathectomy was performed and at the conclusion of the pro cedure the blood vessels appeared to regain some pulsat[illegible] Numerous stellate blocks were performed but they did not [illegible] the situation The hand and forearm progressed to [illegible] and the patient required an emergency guillotine amputa[illegible] the forearm with a subsequent revision of the amputation [illegible]

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scarlet fever diptheria and pneumonia have all produced gangrene of the digits Wilensky *et al*[60] report a case following a chest infection One mechanism for this may be the severe vasoconstriction associated with the infection or with the paroxysms of fever which may occur in such diseases It is conceivable that this constriction could damage the blood vessels with subsequent thrombosis The other possible mechanism for gangrene is the presence of circulating cold agglutins in certain infections which could conceivably precipitate a thrombosis in the smaller blood vessels[61] Forbes[62] was able to collect eighteen case reports together with a case report of his own concerning Raynaud's phenomena associated with autohaemagglutination

A recent patient developed acral gangrene approximately one week after the onset of virus pneumonia resulting in amputation of the portions of several fingers (Fig. 146) No circulating cold agglutinins were found

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Figure 145 Gangrene of hand and forearm caused by massive streptococcal infection.

Examination of the amputated extremity revealed no thrombosis in the radial or ulnar arteries which were found to be in intense spasm One other factor which may have been of importance in the pathogenesis of this condition was that all the superficial veins of the forearm were obliterated by thrombosis due to the numerous previous narcotic injections It is well known that extremities involved with phlebitis are more susceptible than normal ones

Systemic infections such as meningitis malaria typhus typhoid

Figure 146. Acral gangrene secondary to a virus pneumonia. (Courtesy Dr George F Miller)

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CHAPTER 17

PAINFUL STATES

There are several conditions that produce painful states of the upper extremity which should be carefully distinguished from each other so that proper treatment can be given Since all painful states eventually may become fixed by the central nervous system it is important to make the proper diagnosis early and institute treatment as soon as possible to prevent permanent invalidism

DYSTROPHY

Disuse of a part, with or without ischemia of soft tissues will lead to limitation of motion of joints and atrophy of soft tissues Attempted use of such an extremity will result in pain which is confined to the involved anatomical part It is seen more commonly in the elderly individual and in those with a rheumatoid diathesis Treatment consists of physiotherapy to restore motion to the affected part with the occasional use of procaine or hydrocortisone infiltration into the painful areas

PHANTOM LIMB

Amputation of a part almost universally results in some manifestation of the phantom limb Reassurance by the personnel involved when treating such a patient will do much to diminish any painful experiences which might be associated with such a sensation In the majority of cases the phantom limb is of no consequence and becomes subsequently suppressed Rarely if there are emotional or psychiatric problems such sensations may be contorted by the central nervous system to a definite painful phenomenon Occasionally such phantoms may be associated with amputation neuromas or reflex sympathetic dystrophy and correct treatment may relieve the pain

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causalgia since this only adds to the confusion Sympathectomy is of great value in causalgia but it is of no value in the amputation neuroma syndrome In fact the dry skin produced by the operation further alters the sensory pattern reaching the central nervous system and may thereby increase the pain

REFLEX SYMPATHETIC DYSTROPHY

Trauma to an extremity may result in a reflex sympathetic dystrophy which consists of varying degrees of pain vasoneuromotor phenomena and atrophic changes The pain is often a deep boring ache which may be aggravated by cooling the part[3] Occasionally it is burning in character Numerous trigger points may be present, the stimulation of which may produce pain extending to the base of the extremity The vasoneuromotor changes may consist of edema coldness cyanosis sweating cold sensitivity or hypesthesia The disuse resulting from the pain may result in motor weakness muscle atrophy limitation of joint motion osteoporosis and soft tissue atrophy

Such cases should be recognized and treated early to prevent irreversible painful states and severe atrophy In the mild cases physiotherapy and reassurance will suffice However in more severe cases a sympathectomy after a temporary relief by a sympathetic block will be necessary If the physical condition does not permit an operation various vasodilating drugs such as Priscoline (25 to 50 mg q i d.) or Roniacol (50 mg q i.d.) may be successful. In conjunction with these drugs a tranquilizing agent such as Serpasil (0 25 mg t.i d) has proven of benefit in allaying associated emotional distress

A typical case was seen in a sixty two year old dentist who accidently punctured his right thumb while injecting novocain solution Infection occurred around the puncture site which disappeared in two weeks Subsequently the hand became weak and cold and necrosis of the tips of the thumb index and middle fingers developed (Fig 147) Physical examination revealed absent pulses in the wrist and antecubital fossa The blood pressure was unobtainable in the right arm Treatment was instituted twenty three days after the initial injury and consisted of sympathetic blocks Priscoline Roniacol and local treatment to

AMPUTATION NEUROMAS

Neuromas will form at the cut end of an injured nerve or a neuroma in continuity may develop along the pathway of an injured nerve When stimulated they may cause exquisite discomfort in the extremity which usually consists of a pins-and needles sensation or a shooting pain radiating from a localized area. Sometimes the pain may become so severe and diffuse as to spread up the entire extremity This spread of pain from an amputation neuroma to involve the entire extremity may be explained by the fiber interaction in injured nerves [1,2] Another theory is that the painful nerve impulses so stimulate or excite the internuncial pool of the spinal cord that normal impulses reaching this area from the periphery are interpreted as painful This also could occur in higher regions of the central nervous system

Neuromas should be carefully sought for by examination of the wound using a small palpating area as the blunt point of a pencil When there is definite evidence of a localized spot in the scar that will cause severe pain and is associated with paraesthesias or if the neuroma itself may be felt as a discrete mass, operation is indicated Correct surgery demands excision of the neuroma with implantation of the proximal nerve either in soft tissue or in bone Blind excision of scar tissue is of no avail since the neuroma will re insert itself in the subsequent scar

Such painful neuromas often are confused with the phantom limb syndrome since they may appear simultaneously Sometimes excision of an amputation neuroma will relieve a painful phantom *This does not imply that the phantom limb syndrome* is due to the painful neuroma, but only that the painful neuroma so excites and stimulates certain areas of the central nervous system that the phantom sensation becomes painful Routine wound revisions are of no value in the treatment of phantom limb They are of value only when there is a definite painful amputation neuroma which should be treated as such

Painful amputation neuromas should not be confused with causalgia Pain produced by them should not be called minor

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Figure 147 (Top) Reflex sympathetic dystrophy in an elderly man demonstrating gangrene of the tips of the thumb index and middle fingers.

Figure 148 (Bottom) Sub-clavian artery pushed out of usual position by cervical rib.

the necrotic fingertips. Sympathectomy was not done since the patient was considered a poor risk due to associated diseases. Within several days a faint pulse became perceptible in the right wrist. The hand gradually improved with the blood pressure in the right arm returning to 105/85. The fingertips healed and there was no limitation of motion in the fingers or intermittent claudication in the forearm on resuming work.

A specialized form of reflex dystrophy may occur in the upper extremity secondary to a coronary occlusion.[44]

CAUSALGIA

Causalgia, which was first described by Wier Mitchell, is a definite clinical entity which may follow nerve injury. It is a spontaneous pain, hot and burning in character, aggravated by temperature changes and emotions. The involved part is extremely sensitive to touch or even to the suggestion of being touched. It may lead to profound changes in the emotional state of the patient.

Vasomotor manifestations, either vasodilation or vasoconstriction, may be present. In time, the inability to use the extremity will lead to a disuse atrophy.

The cause of this painful state is basically unknown, although a short-circuiting between the sympathetic and sensory nerves at the site of injury explains many of the clinical characteristics.[7] However, there is still the possibility that afferent conduction by way of the sympathetic nervous system takes place giving rise to painful sensations.[8]

Mayfield[9] observed 105 causalgia patients at the Percy Jones General Hospital during World War II. They comprised 5 per cent of all patients admitted to this hospital with peripheral nerve injuries. In the upper extremity the median nerve was most responsible for this disease. He confirmed the fact that sympathectomy brought complete relief of pain whenever it was completely performed. Sympathetic nerve block with procaine produced dramatic temporary relief of the causalgia, but in none of his cases did it give permanent relief even when repeated six to eight times. Shumacker *et al*.[10] in a review of ninety cases of causalgia seen at the Mayo General Hospital during World

Figure 147 (Top) Reflex sympathetic dystrophy in an elderly man demonstrating gangrene of the tips of the thumb, index and middle fingers.

Figure 148. (Bottom) Sub-clavian artery pushed out of usual position by cervical rib.

War II had a somewhat different experience They found that in twenty-one of eighty-three patients in whom one or more *sympathetic nerve blocks were performed* permanent relief of symptoms was obtained. Kleiman[11] had an experience where there were persistent symptoms of causalgia in spite of apparently adequate homolateral sympathectomy A contralateral sympathectomy resulted in complete and continuing relief of pain

SHOULDER OUTLET SYNDROME

The brachial plexus passes underneath the scalenus anticus, over the first rib under the clavicle and pectoralis minor in its course through the shoulder outlet and is vulnerable to pressure by these structures giving rise to various painful syndromes which may affect the hands

The *scalenus anticus syndrome* is produced by compression of the brachial plexus and subclavian artery between the scalenus muscle and first rib A cervical rib may be present to further compress this space either by bony or fibrous band attachment to the first rib The cervical rib may push the subclavian artery so far out of position that it can be seen in the neck (Fig 148) Congenital malformations of the first thoracic rib occasionally may be a factor[12]

Pain occurs along the course of the median or ulnar nerves in a shooting fashion and may be produced by turning the head or pulling the shoulder downward. It may be sharp or merely a dull ache Sensory or motor palsies may occur (Fig 149) Vascular symptoms may be due to local constriction organic changes in the artery or increased sympathetic nerve activity

Adson[13] demonstrated a test which is very reliable in this disease If a patient takes a long deep breath (elevation of first rib) elevates his chin and turns it to the affected side (puts scalenus on stretch and narrows angle between scalenus and first rib) an obliteration of the radial pulse or fall in blood pressure indicates the scalenus anticus syndrome

Surgical treatment consists of exploration of the supra-clavicular area with section of the scalenus anticus muscle permitting the subclavian artery to slide downward along the first rib Resection of the anterior portion of a cervical rib is performed

if it is present. It is to be emphasized that the area should be thoroughly explored since other factors may be present to explain the nerve and vessel compression: anomalous bands and arteries,[14] scalenus medius and minimus muscles,[15] hypertrophied omohyoid muscle.[16]

The *costo-clavicular syndrome* may be produced by compression of the plexus between the first rib and the clavicle. Throwing the shoulders down and back obliterates the pulse.[17] Symptoms may be similar to the scalenus anticus syndrome.[18] Treatment is conservative and consists of postural training. Lord[19] emphasizes that the clavicle may play a serious role in all shoulder girdle syndromes by suggesting that the clavicle be removed in addition to scalenotomy in intractable shoulder girdle syndromes.

The *hyperabduction syndrome* is produced by plexus compression under the pectoralis minor on hyperabduction of the arm.[20] Ischemic changes in the hands appear after sleeping with the arms under the head or after working for extended periods with the arms in hyperabduction. Treatment is by assurance and postural advice.

Other causes of brachial plexus compression may be cervical disks, arthritic spurs and Pancoast tumors of the lung.

Figure 149. Intrinsic muscle atrophy secondary to scalenus anticus syndrome.

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PART V

RECONSTRUCTIVE SURGERY

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CHAPTER 18

SCARS AND MISSING DIGITS

SKIN CONTRACTURES

General Principles

Scar tissue resulting from trauma or other diseases may result in severe limitation of motion in a hand demanding removal with skin replacement Other reasons for scar excision are pain persistent ulceration and the threat of carcinoma

Small linear scars may be corrected by a *Z plasty* In performing this operation the longitudinal wound is excised and limbs the same length as the original wound are extended from each pole of the wound at an angle of about 45 degrees (Fig 150) After these triangular flaps are raised they are transposed This adds length along the line of the defect at expense of width Since lateral mobility is essential with these flaps they are of little value along a finger where such mobility is at a minimum and are of most value in the web spaces

Local rotation or advancement flaps may be useful for covering small defects or transferring skin and subcutaneous tissue to cover tendons leaving a secondary defect in an area which can be covered by a split thickness graft

Most defects in the hand resulting from scar excisions require more extensive free or flap grafting procedures *Flap grafts* are essential to supply subcutaneous tissue as well as skin when secondary bone tendon or nerve procedures are contemplated in the area. A broad based flap is raised in a comfortable place on the abdomen or chest of sufficient size to permit shrinkage of 30 per cent and still adequately cover the defect (Fig 151) If the secondary donor defect cannot be sutured it is covered with a split thickness graft After the graft is sutured into place fixation of the extremity to the body is obtained with adhesive

tape elastoplast or plaster-of-Paris The flap is inspected at frequent intervals to be sure that a change in position has not occurred which could compromise the circulation In three weeks the flap is detached in one or two stages depending upon its vascularity and sutured into position

If tendons or bones are not exposed defects may be covered with *free grafts* Scar and neighboring skin are excised so that the free edges lie lateral to flexion creases (Fig 152) Either the edge of the graft should lie lateral to the flexion crease or a triangular dart be fashioned to accomplish the same purpose Flaps are made to completely cover web spaces

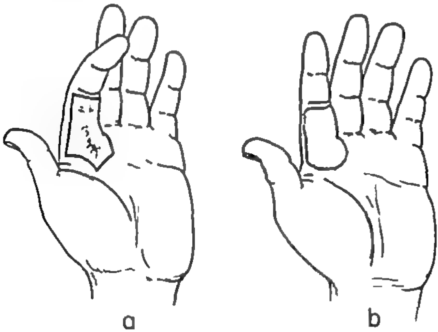

Figure 152. Flexion deformity of finger due to skin contracture (A) Out line of area to be excised to insure lateral suture lines (B) Skin graft in position.

The palmar surface of the hand and fingers requires a full thickness graft to withstand the usual pressures applied to this area When taking full thickness grafts from a hairless region such as the abdominal wall all subcutaneous fat is excised

Dorsal scars are adequately covered by split thickness grafts with care taken to cover the web spaces down to the volar skin The suture lines must lie lateral to a moving joint and not on the dorsal surface.

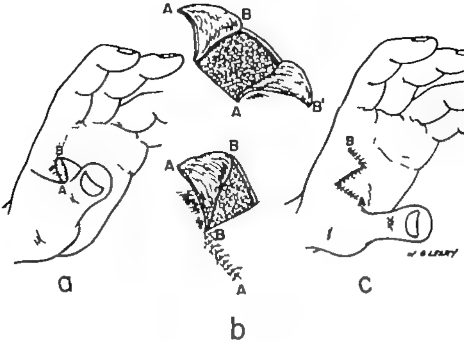

Figure 150 Principles of Z-plasty (A) Longitudinal wound is excised and limbs extended from each pole at an angle of 45 degrees (B) Triangular flaps are undermined prior to transposition (C) Transposed flaps sutured in new position.

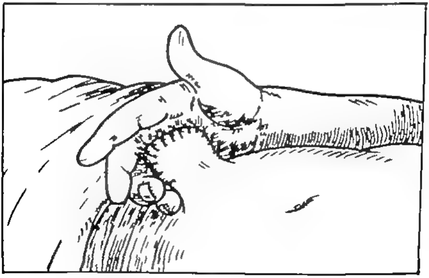

Figure 151 Abdominal flap graft. A broad based flap of sufficient size to account for 50 per cent shrinkage has been applied to defect. Donor site may be covered with a split thickness skin graft.

tape elastoplast or plaster-of-Paris The flap is inspected at frequent intervals to be sure that a change in position has not occurred which could compromise the circulation In three weeks the flap is detached in one or two stages depending upon its vascularity and sutured into position

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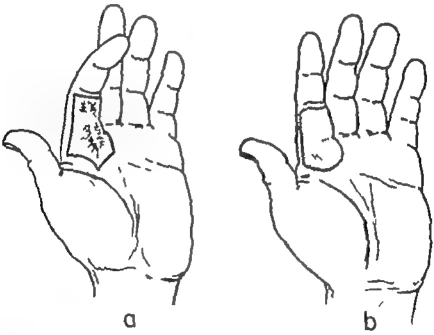

Figure 152. Flexion deformity of finger due to skin contracture (A) Out line of area to be excised to insure lateral suture lines (B) Skin graft in position.

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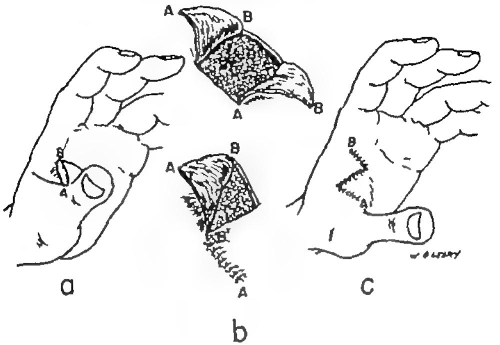

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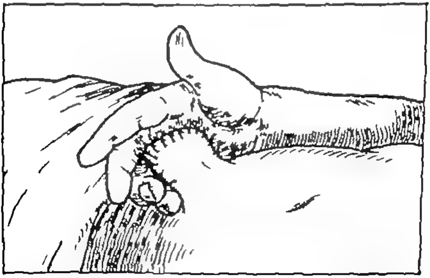
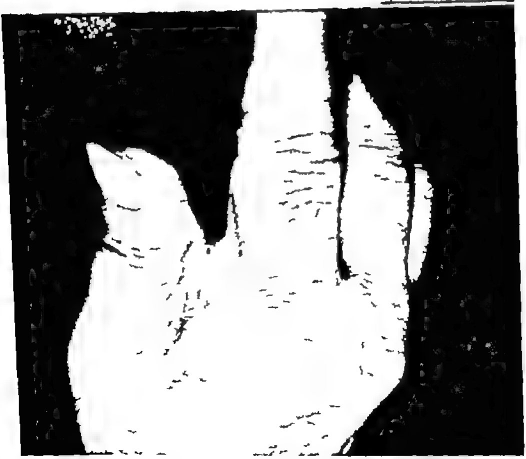


Figure 151 Abdominal flap graft. A broad based flap of sufficient size to account for 50 per cent shrinkage has been applied to defect. Donor site may be covered with a split thickness skin graft.



Special Instances

Web space scars may produce an adduction contracture of the fingers which may be repaired by Z plasty Tanzer[1] reports on interdigital burn contractures of the hand and finds that a lateral flap can be slid from one finger over to the other to cover the

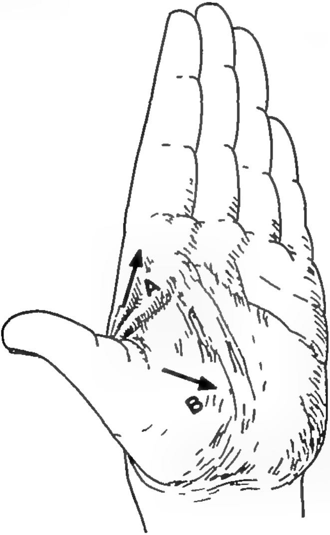


Figure 153 Contractions in the line (A) result in adduction deformity of thumb and along line (B) result in limitation of extention

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Figure 154 (A) Flexion contracture of fingers and adduction contracture of thumb volar aspect (B) Adduction contracture of thumb dorsal aspect

inserted through the first and second metacarpals maintaining the thumb in the proper position of opposition and abduction.* The skin graft is applied and the hand placed in the position of function for three to four weeks after which the graft is cut away and tailored into position.

If there is loss of opponens muscle after such procedures it

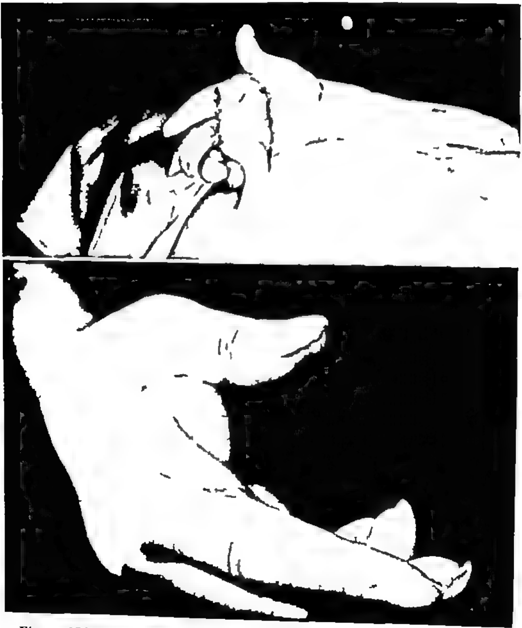

Figure 154 (C) Tubed pedicle graft raised from abdomen and applied to palm of hand (D) Adequate web space has been developed

web space with the resultant defect on the finger replaced by a split thickness graft

Adduction contractures of the thumb are a special problem and many excellent articles have been written concerning them.[24] Maximum spread of the thumb is obtained when the thumb metacarpal is 45 degrees forward from the transverse plane of the palm Wounds or incisions along the web of the thumb or between the base of the thumb and thenar crease will result in contractures (Fig 153) After excision of the contractured area the skin can be replaced by either a Z plasty or a local shifting if the defect is small In most cases in which the palmar surface of the hand is involved a pedicle flap will be necessary taking care that the web space is covered from hinge to hinge

Such a contracture is exemplified in the right hand of a truck driver who sustained a severe burn of the palm and volar surface of the fingers and thumb The initial treatment was not satisfactory in that the web space between the thumb and index finger was not maintained and skin grafting was performed too late As a consequence a flexion contracture of the index, middle and ring finger and an adduction contracture between the thumb and index finger developed (Figs 154A and B) A tubed pedicle graft was raised from the left thoraco-abdominal region Three weeks later the contracted scar tissue was excised and the skin flap inserted into the defect (Fig 154C) After a suitable interval the tube graft was removed from the abdomen and tailored to fit the wound An effective web space was developed and the patient can now resume his former occupation (Fig 154D)

The deeper structures often are involved in such adduction contractures the adductor pollicis, the first dorsal interosseous the extensor pollicis longus and palmar fascia. In such cases the first dorsal interosseous is stripped subperiosteally from its insertion on the second metacarpal bone and the adductor pollicis severed The adherent sheath of the extensor pollicis longus tendon can be shifted radially and the contracted palmar fascia excised Even after this extensive excision of scar there may be such ankylosis of the metacarpocarpal joints that a capsulotomy is necessary In such cases the first metacarpal bone will have to be stabilized in position by using two crossed Kirschner wires

inserted through the first and second metacarpals maintaining the thumb in the proper position of opposition and abduction.[8] The skin graft is applied and the hand placed in the position of function for three to four weeks after which the graft is cut away and tailored into position.

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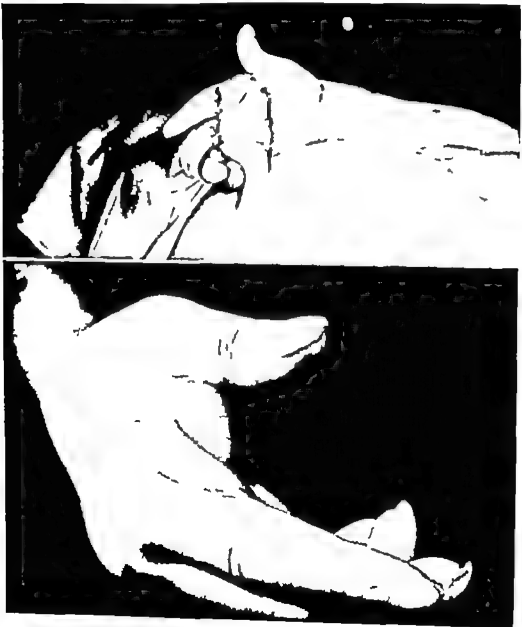

Figure 154 (C) Tubed pedicle graft raised from abdomen and applied to palm of hand. (D) Adequate web space has been developed.

may be restored by an opponens transplant as will be mentioned in a subsequent chapter

Spastic adducted thumbs may be produced by hemiplegia or Erb s palsy where there is no skin defect but rather a contracture of the underlying structures [8] These do not require skin grafting but the deeper structures must be mobilized. Through a dorsi ulnar incision over the first metacarpal bone extending from the metacarpophalangeal joint down to the carpometacarpal joint, the extensor pollicis is isolated and the origin of the first dorsal interosseous stripped from the first metacarpal bone The adductor pollicis is incised and if necessary a carpometacarpal capsulotomy performed The subcutaneous tissue and skin are sutured and the thumb immobilized in full abduction in plaster for three weeks If necessary an opponens transplant operation may be done subsequently

Amputation stumps may be painful if the scar is adherent to underlying bone Revision will consist of excision of the scar and locating the digital nerves either dividing them so that they retract into the subcutaneous tissue proximal to the amputation stump or burying them in bone The bone may be shortened with re suture of the skin flaps or a flap graft applied to the end of the finger depending upon the finger involved In general the length of a thumb index and middle finger are retained at almost any cost, but the fourth and fifth fingers can be shortened without much functional disability Nail bed remnants may continue to grow on an amputation stump requiring resection of the nail bed.

AMPUTATIONS

Thumb

Complete use of the thumb requires good sensation adequate abduction to permit grasping and sufficient length to supply pinching The latter may be done through a thumb-finger or thumb-palm pinch and one s occupation should determine which should be reconstructed Regardless of the length of the thumb abduction is necessary not only to permit grasping by the thumb

but to allow flexing fingers to reach the palm The treatment of adduction deformities already has been mentioned

Amputations through the *distal phalanx or distal interphalangeal joint* rarely require any reconstruction unless there is a painful sensitive fingertip The scar is excised and skin coverage applied either by a free or flap graft Rarely at the time of initial thumb injury the proximal portion of an index finger also may be severely damaged leaving the distal end relatively intact Barsky [7] suggests that this distal end of the index finger be transferred to the tip of the thumb At the primary operation a mid-dorsal incision is made on the index finger from the proximal to the distal joint The extensor tendon is reflected to one side and the digital nerves and vessels preserved The bones of the proximal two phalanges are removed thus leaving a tube of skin its distal end consisting of the index fingertip and its phalanx with the digital vessels and nerves The distal end of the thumb stump is freshened by performing a guillotine amputation through the distal joint The fingertip is then migrated to the thumb stump the extensor tendon of the index finger is sutured to that of the thumb and the adjacent skin edges are approximated Six weeks later nerve suture is performed between the fingers by mid lateral incisions At this same operation the digital arteries and the pedicle of the index finger are divided Six weeks later the third stage is performed and the flexor profundus of the index finger is sutured to the long flexor of the thumb to stabilize the joint.

Amputations through the *distal portion of the proximal phalanx* may be repaired by a plastic flap fashioned so that its tip will be covered by normal thumb skin thus giving better sensation [8] A curved incision is made across the radial border of the hand proximal to the tip of the stump outlining a flap based on the dorsal and ulnar surfaces This incision is carried through the fascia plane down to the bone which is mobilized This entire flap is dislodged A bone graft is then inserted in the remaining bone and extended into the pocket of the flap which has been previously developed The raw area may be covered with a split thickness graft following which a pressure dressing is applied and the hand maintained in a plaster-of Paris cast. Lewin [9] de

scribes such a case and maintains that it has better skin sensation than a pedicle graft.

Amputations through the proximal phalanx or metacarpal adjacent to the metacarpophalangeal joint, *leaving a major portion of the metacarpal intact* may be repaired by opening the first web space to restore a thumb-palm pinch or by a plastic lengthening procedure to restore a thumb-finger pinch

The thumb-palm pinch is adequate for many occupations and can be achieved without too much difficulty in cases where there is at least an intact metacarpal present The web of the thumb is divided dorsally along the edge of the first metacarpal and volarly along the thenar crease thus forming a volar and dorsal flap The first dorsal interosseous muscle and the head of the adductor pollicis are incised and removed The volar and dorsal flaps are sutured in place with the volar flap sutured to the back of the thumb If in such injuries there has been amputation of the index finger the second metacarpal bone may be removed in order to deepen the web space between the thumb and adjacent metacarpal

In order to restore a thumb-finger pinch, a tube pedicle graft is applied to the end of the thumb in which is inserted a bone graft. Nicolodani produced a skin tube and inserted bone into the tube before it was placed in the first metacarpal bone. Many authors believe that it is best to apply the tube pedicle and after it has been removed from the abdominal wall to insert a bone graft [10-14] A tube pedicle is raised in the standard fashion on a convenient portion of the abdomen or thorax after which the appropriate end of the tube pedicle is detached and sutured to the freshened thumb stump It is necessary to have the largest possible surface contact between the two areas and a ring suture line around the stump is undesirable In cases where a shorter tube is necessary a simple tube flap may be elevated and attached to the thumb at one stage. When one is certain that the tube pedicle has regained its blood supply which usually requires three weeks the pedicle is detached from the abdominal wall Since the terminal suture line has the least vascularity the skin sutures are removed later than usual After the tube has healed completely a bone graft is inserted Various donor sites have

been used such as iliac crest tibia rib or metacarpal bone An incision is made at the base of the pedicle attachment and the end of the bone is exposed and its medulla gouged out The bone graft is shaped inserted into the tube pocket and pegged into the previously prepared metacarpal The finger is then splinted with a plaster-of-Paris cast and left undisturbed for approximately a month

Amputations which leave only *a minor portion of metacarpal intact* will require either the lengthening procedure which has been described or transfer of a finger or toe

Pollicization of the index finger has been attempted with varying degrees of success [15-22] The technique utilized by Gosset [22] appears to be a useful one and is as successful as most The first phase of the operation (Fig 155A) consists of a circular incision on the scar of the amputated thumb and around the base of the index finger passing through the middle of the commissure of the second interspace a good centimeter beyond the metacarpophalangeal joint. The two incisions are united by a U-shaped flap on the dorsal surface of the first interspace An amputation of the distal phalanx of the index finger is done to shorten the finger so that it will approximate the length of a normal thumb

The second stage consists of isolation of the neurovascular bundle which is dissected toward the palm of the dorsal skin flap The digital artery on the radial side of the middle finger is divided about a centimeter from its bifurcation in order to preserve the blood supply of the ulnar side of the index finger (Fig 155B) The superficial and deep fascia of the palm are incised and the intermetacarpal ligament severed Thus this permits the second interspace to be opened The next phase consists of preparation of the remainder of the first metacarpal or the multangular if necessary (Fig 155C) If present the flexor tendon of the thumb is resected and a mortise is made in the metacarpal about four millimeters wide and one centimeter deep Two small transverse holes are placed through the two flanks of the mortise. The first interosseous and adductor of the thumb are separated as far as possible

The next phase consists of isolation of the second metacarpal

The extensor vinculi are cut following which the second dorsal interosseous is removed from the side of the second metacarpal bone The first dorsal interosseous and the first volar interosseous are severed some distance from their insertion in the second metacarpal and the bone is sectioned at an appropriate place to give the new thumb proper length A tendon is prepared at the base of the second metacarpal in such a way that when placed in the mortise of the first metacarpal the thumb will be in the position of opposition

The next phase consists of placing the bones in position and passing metal wires through the two holes in the flanks of the mortise to secure the bone (Fig 155D) The abductor pollicis is sutured to the severed first dorsal interosseous and the adductor pollicis to the first volar interosseous The extensor tendon of the thumb may be sutured to the extensor of the

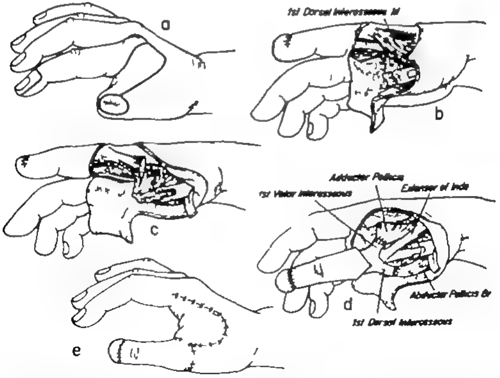

Figure 155 Pollicization of index finger (A) Initial incision (B) Isolation of neurovascular bundle (C) Preparation of mortise in first metacarpal (D) Second metacarpal positioned into first metacarpal. Abductor pollicis sutured to first dorsal interosseous and adductor pollicis sutured to first volar interosseous (E) Skin flap sutured in position

index finger but this is not essential. The flap which was previously raised is now used to cover the new web between the index and third fingers and a pressure dressing is applied (Fig 155E). A plaster cast is applied which is left in place for three to four weeks. Tips of fingers should be appraised for circulation.

Many authors do not like to damage an intact index finger and only pollicize an index finger that has been previously injured. If this is normal, other fingers are apt to be used such as the third or fourth.[1,20] Letac[76] reports a series of seven cases where he pollicized the ring finger. He makes a racket incision in the ring finger with the long arm of the racket placed dorsally. The extensor tendon is sectioned over the middle third of the metacarpal. The metacarpal is severed at a previously determined level and the neurovascular bundles are isolated and freed as much as possible. The flexor tendons are freed proximally and distally and thus one has a neurovascular and tendinous pedicle which insures motion, nutrition and sensation to the transposed finger. The scar of the thumb amputation is excised and the base of the first metacarpal prepared for the transferring bone. The ring finger is then pulled through a previously made opening between the palmar aponeurosis and the flexor tendons of the middle and second fingers avoiding twisting of the pedicle. The metacarpal bone and the proximal portion of the phalanx are then excised at a proper level to give adequate length to the thumb, and the bones are placed together by either a mortise and tenon joint or internal fixation. The extensor tendon of the fourth finger is sutured to the extensor tendon of the thumb. The adductor of the thumb is sutured to the interossei of the fourth finger and the same with the thenar muscles. The wound is closed after suturing the intermetacarpal ligaments between the third and fifth fingers. The hand is placed in a plaster-of-Paris cast leaving the tips of the fingers free. If adequate skin is not present to create a commissure between the thumb and index finger, a flap is mobilized and placed in position. One operation out of the seven resulted in gangrene.

In rare instances when all the fingers but the index are missing it may be necessary to transfer the fifth metacarpal. Littler[22] reports such a case where the fifth metacarpal with its intrinsic

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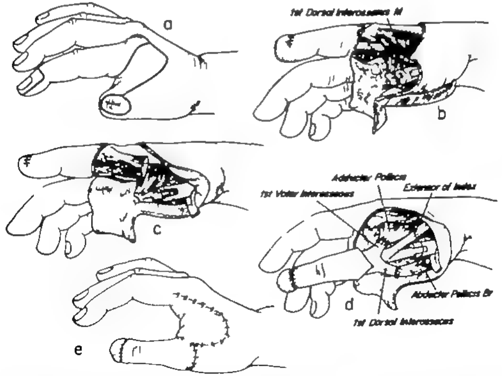

Figure 155 Pollicization of index finger (A) Initial incision (B) Isolation of neurovascular bundle (C) Preparation of mortise in first metacarpal (D) Second metacarpal positioned into first metacarpal Abductor pollicis sutured to first dorsal interosseous and adductor pollicis sutured to first volar interosseous (E) Skin flap sutured in position.

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muscles was transferred to the thumb site on a narrow skin pedicle containing the ulnar nerve and vessels

Since Nicoladoni first described the operation many toe transfers have been performed Although the method is supposed to give a stiff finger with poor function Clarkson,[27] reports fifteen of these transfers and believes the method is safe giving movement not only to the restored part but also a growing nail Byars[25] reports this type of transplant which was followed for twelve years and states that the digit is almost normal save for some tapering There is no active movement in the terminal joint but sensation is excellent

Loss of All Digits

The loss of all digits is an extremely crippling deformity Graham *et al*[31] describe four cases of this deformity where they created a lobster-claw type of hand by elongating the first metacarpal and excising the shaft of the second metacarpal leaving only the base thus creating a cleft between the third and first metacarpals by bringing a rectangular flap of skin from the dorsum of the hand through the cleft and suturing it to the base of the palmar wedge The palmar skin obtained by excising the second metacarpal is sutured dorsally into the cleft onto the opposing surfaces of the first metacarpal Higgins,[28] describes a procedure where the second and third metacarpals the lesser multangular and the body of the capitate bone are excised for a similar condition Since an S-shaped incision is used for the procedure the first metacarpal is covered with palmar skin and the third and fourth metacarpals with dorsal skin The resultant stump in this individual had surprisingly good grasping function and was quite suitable for manual labor Vogl[29] presents a case where the entire hand was lost down to the bases of the meta carpals Gripping was obtained by skin flaps strengthened with two grafts from the tibia which were placed into the bases of the first and second metacarpals producing some grasping func tion Murray[30] reports two interesting cases where all the fingers were lost The fourth finger of the opposite hand was transferred to the index metacarpal and a thumb was fashioned by the use of a tube graft with ultimate iliac bone grafting into the thumb metacarpal

CHAPTER 19

TENDON RECONSTRUCTION

TENDON GRAFTS

When tendons are destroyed by trauma, burns or infection, tendon grafts are necessary. The most frequent injuries requiring tendon reconstruction are those in the digital sheaths between the metacarpophalangeal and proximal interphalangeal joints. Primary tendon repair in this area is unsuccessful since the tendon anastomosis lies within a narrow digital tunnel. Webster[1] believes that the angle of the tendon pull in this region prevents it from exerting normal strength in breaking down postoperative adhesions. Other important factors are unnecessary trauma at operation, incorrectly placed incisions, suture material that is too heavy, operating in a bloody field without a tourniquet, inadequate suture technique, and too early motion.

The tendon graft is nourished by blood vessels at the insertion of the graft and by other blood vessels along the subcutaneous tissues of the finger. Braithwaite and Brockis amputated a finger which had a previous tendon graft eighteen weeks prior to amputation. They injected the vessels with colloidal silver iodide and dissected the finger and found the pattern of vessels within the graft to be similar to the normal vascular pattern except that it was not so profuse.

There are certain *principles of tendon grafting* which must be adhered to regardless of the tendon involved.[2-7] Adequate motion in the joints of the involved finger and a normal circulation are essential. It is preferable to have a sensitive finger, but if there is nerve damage, it can be repaired at the time of the tendon graft. At the time of operation scar tissue should be completely removed. If skin and subcutaneous tissue is not present over the tendon injury, it must be replaced with a flap graft before tendon reconstruction. The annular ligaments in the

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The profundus tendon is removed from the distal phalanx leaving a small cuff of insertion intact to permit approximation. The flexor digitorum profundus and sublimis are removed from the tendon sheath. They are severed in the proximal portion of the palm so that the subsequent anastomosis of the graft with the proximal end of the tendon will lie at a distance from the digital tunnel (Fig. 156b). The digital sheaths are excised except

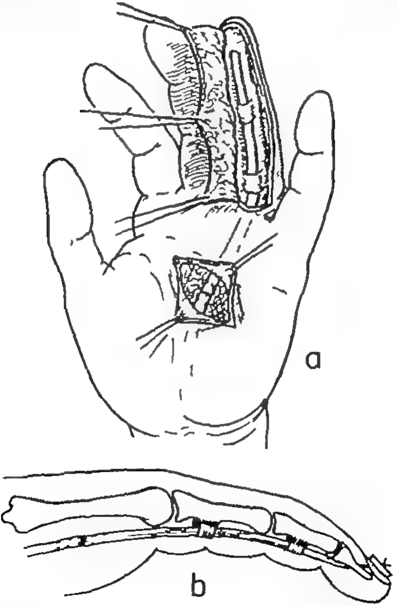

Figure 156. Principles of tendon grafting (a) plan of incisions (b) Proximal anastomosis placed away from digital tunnel. Annular ligaments left over proximal and middle phalanges.

fingers are preserved as much as possible to prevent bow stringing on flexion but if they have been destroyed they can be reconstructed. The donor tendon is transplanted whenever possible with its paratenon intact. The tendon graft is performed within four to six weeks following injury since after this the fibrous sheath collapses the muscles become fixed and contracted and the tendons are frozen in position

The source of the tendon graft is usually the palmaris longus tendon when present. In a study of 1 000 hospital patients Rank and Wakefield [7] found the palmaris longus present on both sides in 69 6 per cent of males and 71 2 per cent of females on the right side only in 6 8 per cent of males and 7 4 per cent of females on the left side only in 7 per cent of males and 6.2 per cent of females Both tendons were absent in 16 6 per cent males and 15 2 per cent of females This tendon is obtained by a longitudinal incision in the forearm taking care that the paratenon is removed with the graft.

Another good tendon source is the extensor longus tendon to the second third or fourth toes which may be removed by a curvilinear incision over the dorsum of the foot taking care to remove the paratenon with the tendon Other sources of tendons are the flexor digitorum sublimis of the injured hand and rarely the peroneus longus and plantaris tendons

The *flexor tendons* usually are approached in a bloodless field by an incision on the lateral side of the finger and by a transverse incision in the palm along the distal palmar crease

Rank and Wakefield [7] use incisions that permit a skin flap to be developed which allows wider exposure and more meticulous dissection For the index and fifth fingers the incision along the lateral side of the finger is curved transversely in line with the palmar creases proximally and across the pulp of the terminal phalanx distally The digital nerves and vessels on the incision side of the finger are left dorsal to the incision but those on the opposite side are carried in the skin flap For the middle and ring fingers the proximal pole of the incision is curved transversely in line with the proximal digital crease Exposure of the tendons in the palm is obtained through the usual transverse incision in the line of the palmar crease (Fig 156a)

The profundus tendon is removed from the distal phalanx leaving a small cuff of insertion intact to permit approximation. The flexor digitorum profundus and sublimis are removed from the tendon sheath. They are severed in the proximal portion of the palm so that the subsequent anastomosis of the graft with the proximal end of the tendon will lie at a distance from the digital tunnel (Fig. 156b). The digital sheaths are excised except

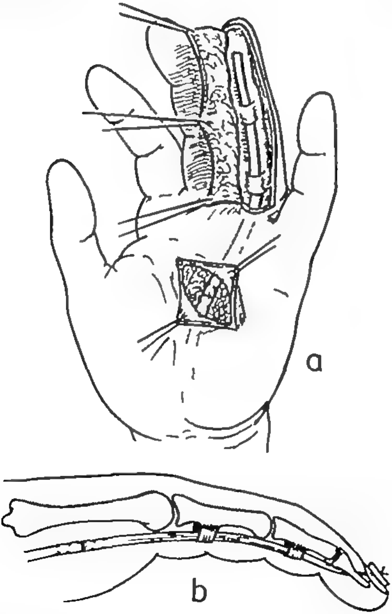

Figure 156. Principles of tendon grafting (a) plan of incisions (b) Proximal anastomosis placed away from digital tunnel. Annular ligaments left over proximal and middle phalanges.

for two annular ligaments over the middle and proximal phalanges If this is not possible an annular ligament is constructed using a portion of tendon Bunnell s,[8] method is to place a slip of tendon around the phalanx at the site of maximum tension and suture it as a ring This ring of tendon is slipped around so that the sutures are on the bone side and a free smooth tendon surface overlies the tendon graft. In the proximal phalanx the slips of the flexor digitorum sublimis can be attached to the fibrous remains of the digital tunnel and form a satisfactory retaining ligament

The tendon graft is threaded through the preserved annular ligaments and the distal portion of the graft inserted into the distal phalanx through either a hole or bone flap Flynn s[*] method of anastomosis is quite satisfactory A No 0 plain catgut suture is placed in the end of the grafted tendon and the two strands of catgut threaded through drill holes in the distal phalanx and tied over a button on the dorsum of the distal phalanx. To reinforce this suture a No 3 silk suture attaches the distal end of the tendon to the old profundus tendon The incision in the finger is closed, since it has been found that attempting to suture the finger while it is held in the flexed position is awkward

The proximal suture is performed using No 3 silk with a Bunnell zig zag technique. If there is a great discrepancy in the size of the tendons the tendon graft may be threaded through a small slit in the proximal tendon and held in place with several interrupted sutures The correct tension on the suture line is of great importance Koch[3] recommends slight tension on the anastomosis site with the wrist flexed 20 degrees the metacarpophalangeal joint flexed 30 degrees and the interphalangeal joints slightly flexed

Tendon grafts for the *flexor digitorum pollicis* involve the same principles as those in the fingers The incision is made on the ulnar side of the thumb and thenar eminence and in

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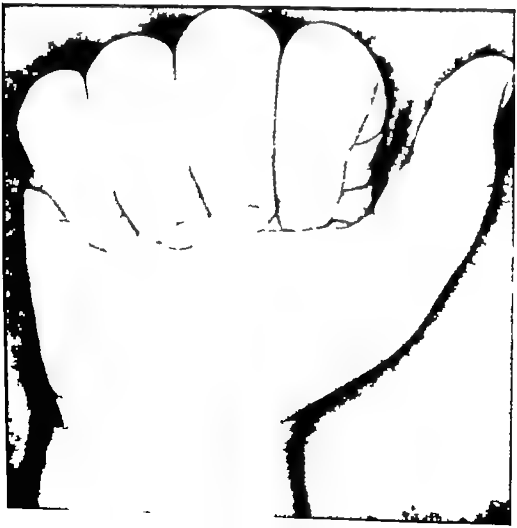
Figure 157 Results from lengthening flexor digitorum profundus at wrist and advancing it into distal phalanx (A-top) good extension (B-bottom) excellent flexion (Courtesy Dr Anthony Zovickin.)



the wrist. The tendon is removed from its insertion in the distal phalanx to above the wrist. This will give a proximal anastomosis in an area where the pull of the tendon is in a straight line rather than where its direction changes At the end of the procedure the wrist is flexed to about 45 degrees and the interphalangeal and metacarpophalangeal joints of the thumb flexed 30 degrees Instead of grafting a transfer of the flexor digitorum sublimis of the ring finger to replace the damaged flexor pollicis longus is a useful procedure

When flexor tendons of the thumb and fingers are severed within an inch from their insertion into the distal phalanx they may be advanced by lengthening the flexor profundus tendon at the wrist or severing the tendon attachment of the flexor pollicis longus and sliding it along its insertion The distal tendon can then be inserted into the distal phalanx A recent case is cited as an example of this principle A young man with severed flexor profundus and sublimis tendons at the proximal interphalangeal joint of the finger was explored and after excision of the sublimis, the profundus was lengthened in the wrist so that the severed proximal tendon could be advanced into the distal phalanx. Excellent extension and flexion was obtained (Figs 157 a and b)

Extensor tendon grafts are seldom necessary However if the tendon to a finger is completely lost, it may be necessary to graft using an extensor of the toe or the palmaris longus The usual extensor tendon injuries following burns and crushes involve such diffuse destruction of tissue that tendon grafting becomes a minor part of the reconstruction If the extension contracture of the finger is associated with a severe destruction of the joints and skin it may be better to fuse the metacarpophalangeal joint in a position of function If adequate skin coverage excision of collateral ligaments elevation of the dorsal hood and stripping of the volar plates restores joint motion a tendon graft may be inserted Following extensor tendon grafts the correct position is 40 degrees dorsal extension of the wrist 180 degrees extension of the metacarpophalangeal joint and the fingers slightly flexed

Although tendon grafts as a rule are unsatisfactory when joints are ankylosed it may be possible to restore joint function

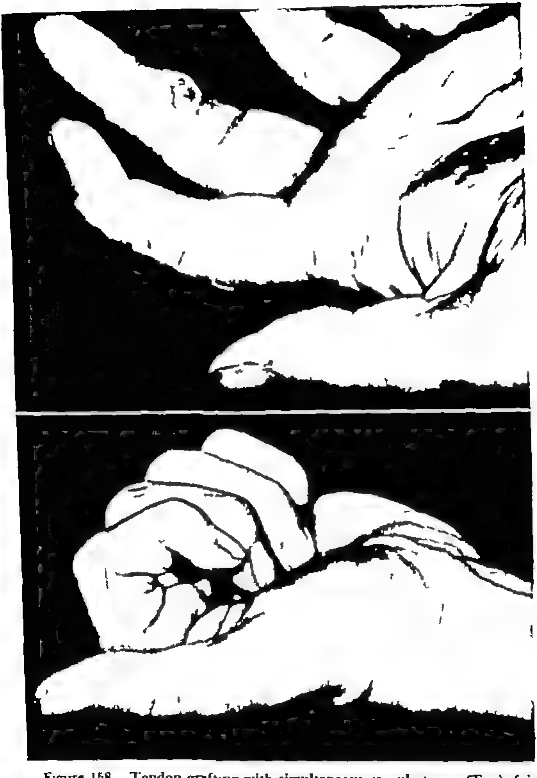


Figure 158. Tendon grafting with simultaneous capsulectomy (Top) fair extension (Bottom) fair flexion.

at the same time the tendon graft is performed if the contracture is limited to joint capsule and the joint surfaces are uninvolved In a recent case a young man suffered a laceration of the profundus and sublimis tendons over the proximal interphalangeal joint of the index finger associated with severe joint damage. This joint became fixed at about 5 degrees of flexion with no active or passive motion possible Three months following injury a tendon graft was performed after a capsulectomy permitted good passive joint motion He now has fairly good extension and flexion (Figs. 158 a and b) The exception does not disprove the rule however that in most cases joint function should be restored before grafting is attempted.

After tendon grafting the hands are kept in the proper position by a plaster cast for three weeks followed by removal of sutures and institution of physiotherapy

The patient's mental drive and initiative are of profound importance in the recovery of tendon grafts Occasionally a patient will be reluctant to put sufficient pull on a tendon to free the adhesions along the sheath because of pain Graham[9] found it useful to block the median or ulnar nerve and thus promote flexion in the anesthetized finger

Boyes,[10] analyzed 188 tendon grafts for flexor tendon damage in the critical zone When there was no secondary joint damage or scarring, he found that all could flex their fingers within 1½ inches in the palm 90 per cent within 1 inch 35 per cent within ½ inch and 10 per cent could completely flex the finger down to the distal crease When there was joint or multiple damage the results were not as good.

Ender[11] reported 12 5 per cent failures in seventy grafts and Kinmonth[12] four failures out of twenty-one grafts Tendon grafting to the little finger is the least successful and for this reason it probably is seldom necessary and should not be done unless there is a special reason such as the patient's occupation

TENDON TRANSFERS

The usual indication for tendon transfer is the restoration of motion lost by a permanent nerve paralysis. Occasionally transfers are performed as a type of dynamic splinting for prolonged

temporary nerve palsy For instance following a radial nerve injury in the axilla wrist and finger extension might not return for eighteen to twenty four months An early tendon transfer could be done to replace the usual cock up dynamic splinting and insure better hand function when and if recovery of the nerve occurs Rarely tendon transfers are done in lieu of grafting to replace damaged tendons

Radial Nerve Palsy

The pioneer work on tendon transfer for loss of the extensors of the fingers and thumb was done in the early decade of this century with a resurgence of interest following World War II [13] The combined experience of these authors plus the experience of the Hand Service at the Boston City Hospital emphasizes certain cardinal points of this repair

The pronator teres serves as an adequate extensor of the wrist when it is inserted into the extensor carpi radialis longus (Fig 159) Guilleminet [15] believes that this muscle should be fixed into both radial wrist extensors since insertion into the extensor carpi longus alone produces radial deviation The flexor carpi ulnaris when transplanted dorsally serves as an adequate extensor of the fingers This tendon is inserted obliquely through the four extensors of the fingers with the fifth finger insertion more proximal than that of the index finger It is essential that the tendon either insert into the extensor communis tendons proximal to the dorsal carpal ligament or else the dorsal carpal ligament should be partially excised so that the suture lines will not be fixed in this tunnel The separate movements of the thumb are carefully preserved in the transfer and the extensor carpi ulnaris which has passed through the extensor communis digitorum tendons should end terminally in the extensor longus pollicis tendon restoring thumb extension Abduction of the thumb is restored by the anastomosis of the palmaris longus or the flexor digitorum sublimis of the ring finger to the abductor pollicis longus

It is essential that one of the strong wrist flexors be retained to prevent flexion weakness of the wrist The author has seen one case where all the wrist flexors were transferred to the back

of the hand resulting in a severe hyperextension contracture of the wrist

This operation may be performed using several longitudinal incisions on the volar surface of the hand a curvilinear incision on the dorsum of the hand for insertion of the flexor carpi ulnaris into the finger and thumb extensors and a relatively small longitudinal incision for insertion of the other flexor into the

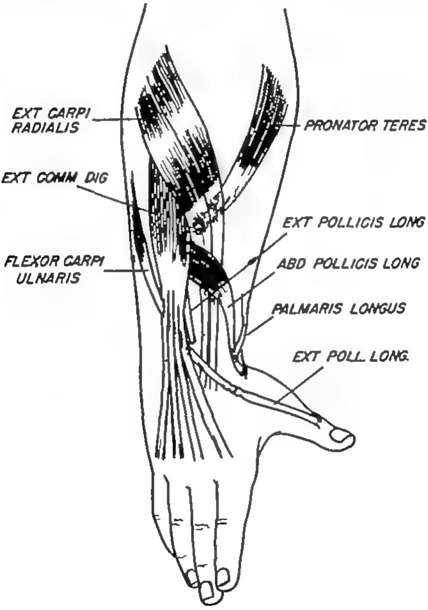


Figure 159 Tendon transfers for radial nerve palsy

abductor of the thumb The operation is done in a bloodless field and at the conclusion of the procedure the tension on the tendon anastomosis should be sufficient to keep the wrist in 20 degrees dorsiflexion the metacarpophalangeal joints extended and the interphalangeal joints in about 15-20 degrees flexion The thumb is held in extension and abduction

The final assay of results should take into consideration not only the range and power of extension of the fingers thumb and wrist but also the range and power of wrist and finger flexion [4]

For extensive palsies of the hand which include the flexor muscles as well as the extensors it may be necessary to fuse the wrist and utilize various wrist movers for transfers In such instances a tenodesis may be preferable The original tenodesis of Perthes where the extensor carpi radialis longus and brevis are cut above the dorsal carpal ligament and fixed to the periosteum of the radius has been utilized in several instances in association with tendon transfers [14]

Occasionally isolated transfers of tendons are necessary to restore individual losses. For example Burman [23] reports the transplantation of the extensor carpi ulnaris to the base of the first metacarpal into the abductor pollicis longus in the case of a spastic hand where the thumb was drawn into the palm At the same time he performed a stripping of the thenar and adductor muscles of the thumb This transfer may be of value in cases of isolated paralysis of the deep radial nerve To restore extension and abduction of the thumb it may be useful to transfer the extensor proprius indicis into the extensor pollicis longus

Median Nerve Palsy

Although opposition and abduction of the thumb are both essential to the proper function of the hand the loss of abduction is the more serious defect, since this interferes markedly with grasping The procedures useful in restoring these essential functions depend upon whether or not the palsy is high or low in the median nerve In the most common variety the *median nerve is damaged low* in the forearm giving a loss of opposition and abduction but good flexion of the thumb and

fingers The principles outlined by Bunnell [70] are of paramoun importance for this type of injury He believes that the tendon transfer should pass subcutaneously in a line between the meta carpophalangeal joint of the thumb and pisiform bone The insertion of the tendon should be on the dorsal ulnar aspect of the base of the proximal phalanx of the thumb and pass directly over the summit of the metacarpophalangeal joint and not distal to it. It is well to remember that the metacarpophal angeal joints of various individuals differ tremendously in ability to flex If a person has a relatively rigid metacarpophalangeal

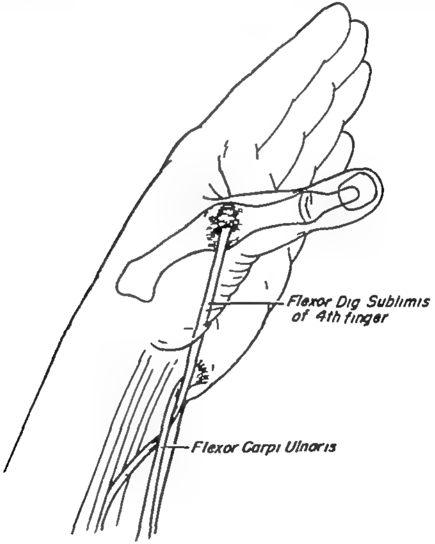


Figure 160 Tendon transfer for median nerve palsy with loss of opposition and abduction

joint the flexor digitorum sublimis tendon can be inserted on the dorsal ulnar aspect of the capsule and extensor mechanism at the base of the proximal phalanx However if a person has a hyper mobile metacarpophalangeal joint it is best to split the tendon of the flexor digitorum sublimis inserting one half proximal to the joint and the other distal to the joint on the dorsal ulnar aspect otherwise one may obtain an incapacitating flexion of this joint when attempting abduction and opposition

Various combinations of pulleys tendons and motors have been used One of the most successful variants of this operation is the one in which the flexor digitorum sublimis of the ring finger is removed from its attachment to the middle phalanx pulled out through the wrist looped around the flexor carpi ulnaris and brought subcutaneously through a tunnel to be inserted into the proximal phalanx of the thumb (Fig 160) This is a very satisfactory type of transfer (Fig 161) as has been noted by most surgeons in this field [illegible]

Figure 161 Restoration of opposition and abduction by transfer of flexor digitorum sublimis of fourth finger to dorso-ulnar aspect of metacarpophalangeal joint of thumb using flexor carpi ulnaris as a pulley

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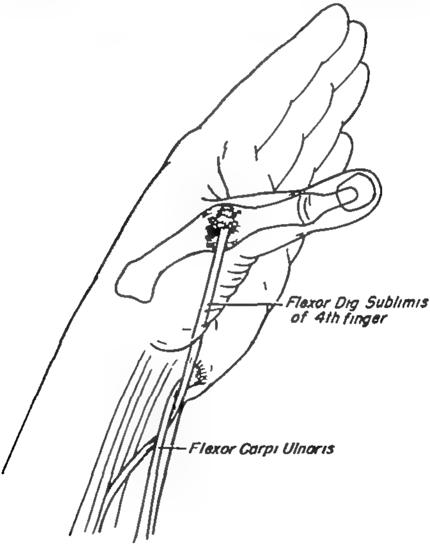

Figure 160 Tendon transfer for median nerve palsy with loss of opposi tion and abduction.

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Figure 161. Restoration of opposition and abduction by transfer of flexor digitorum sublimis of fourth finger to dorso-ulnar aspect of metacarpophalangeal joint of thumb using flexor carpi ulnaris as a pulley.

Thompson [30] describes another operation for opponens paralysis in which the flexor digitorum sublimis tendon is removed through an incision in the palm after sectioning it at the base of the ring finger An incision is made on the dorsal surface of the proximal phalanx of the thumb and the flexor sublimis tendon is brought through a subcutaneous tunnel across the thenar eminence The tendon is split longitudinally and one end is inserted into the distal end of the metacarpal of the thumb and the other into the proximal phalanx. Kirklin and Thomas [29] believe the Thompson operation is especially suitable when there is scarring over the distal half of the forearm which would prevent a tendon transfer in this area Another point concerning this transfer deemed necessary to mention here is that loss of opposition and abduction of the thumb results in two different types of weakness the inability to abduct the thumb for grasping and adducting and opposing the thumb against the fingers The author believes the hand should be evaluated for its main purpose and the function most severely destroyed restored For example if the patient s occupation requires abduction of the thumb as the primary need the Bunnell procedure is indicated. However if his occupation involves the pinch of the thumb against the fingers the Thompson procedure would restore this function best

Goldner and Irwin [28] analyzed various procedures of value for paralysis of the thumb particularly when it is associated with other problems in the hand For instance if some of the extrinsic strength of the thumb is missing it must be restored before the opponens operation is done If the extensor pollicis longus is weak the extensor carpi radialis longus can be sutured to it. In the flexor pollicis is weak the flexor digitorum sublimis of the index or middle finger can be sutured into the tendon at the wrist. If the thumb has been lacking abduction and opposition for any length of time an adduction contracture will take place which may require capsulotomy of the metacarpophalangeal joint of the thumb cutting of the fascia between the first and second metacarpals stripping of the first dorsal interosseous from the first metacarpal bone division of a contracted adductor pollicis muscle at its point of insertion and capsulotomy of the carpometa

carpal joint If the carpometacarpal is hypermotile it may be necessary to fuse it before the flexor sublimis transplanation is performed

When the *median nerve palsy is high* so that the flexors of the index finger and thumb are paralyzed the previously mentioned procedures are of no avail Flexion of the index and middle fingers can be obtained by suturing their tendons to the deep tendons of the fourth and fifth fingers Brooks[18] found that lateral hitching of the paralyzed tendons of the index finger to adjacent non paralyzed tendons was universally unsuccessful and believes that for this part of the transfer the deep flexor of the ring finger should be sutured directly to the deep flexor of the index finger Flexion of the thumb can be obtained by suturing the extensor carpi longus to the flexor pollicis longus Opposition may be restored by a bone block or tenodesis between a re routed extensor pollicis brevis and palmaris longus using the flexor carpi ulnaris as a pulley

If the forearm muscles are too weak for transfer a stabilization procedure will be needed However good flexion of the fingers and relatively strong abduction of the index finger are essential for a useful grasp and pinch Although an arthrodesis of the carpometacarpal joint may restore the angle between the first and second metacarpals the most popular operation appears to be a bone block between the first and second metacarpal

Brooks[31] describes a bone block which he performed in sixteen cases as follows

Two curved incisions are made over the first and second metacarpals so that the scars do not overlie the graft at any point. The shafts of the metacarpals are exposed subperiosteally and if there is any contracture of the adductor pollicis the muscle is divided at its insertion and full passive correction obtained The terminal part of the radial artery is not exposed deliberately nor indeed should it be seen A narrow osteotome is passed across the space deep to the first dorsal interosseous muscle so that it lies over the middle of the shaft of each bone the thumb is then placed in full palmar abduction and the length of graft required is noted

Thompson [30] describes another operation for opponens paralysis in which the flexor digitorum sublimis tendon is removed through an incision in the palm after sectioning it at the base of the ring finger An incision is made on the dorsal surface of the proximal phalanx of the thumb and the flexor sublimis tendon is brought through a subcutaneous tunnel across the thenar eminence The tendon is split longitudinally and one end is inserted into the distal end of the metacarpal of the thumb and the other into the proximal phalanx. Kirklin and Thomas,[29] believe the Thompson operation is especially suitable when there is scarring over the distal half of the forearm which would prevent a tendon transfer in this area Another point concerning this transfer deemed necessary to mention here is that loss of opposition and abduction of the thumb results in two different types of weakness the inability to abduct the thumb for grasping, and adducting and opposing the thumb against the fingers The author believes the hand should be evaluated for its main purpose and the function most severely destroyed restored For example if the patient s occupation requires abduction of the thumb as the primary need, the Bunnell procedure is indicated However if his occupation involves the pinch of the thumb against the fingers the Thompson procedure would restore this function best.

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Ulnar Paralysis

Loss of the interossei and lumbricals result in the "claw" or "intrinsic minus" hand. There is a flexion contracture of the interphalangeal joints and an extension or hyperextension position of the metacarpophalangeal joints. With lesions involving the ulnar nerve alone, this deformity affects only the fourth and fifth fingers; however, with the combined median and ulnar nerve paralysis, it involves all four fingers. Extension of the distal and proximal interphalangeal joints can be performed by the extensor communis tendon through its action on the lateral bands if the proximal phalanges are held in slight flexion or if the wrist is flexed. On the other hand, if the metacarpophalangeal joints or the wrist are held in extension, the extensor tendons have little affect on extension of the distal phalanges. If contraction of the metacarpophalangeal joints occurs so that hyperextension is impossible, the claw deformity is less obvious. This is also true if the nerve lesions responsible for the claw deformity are high enough to paralyze the flexors of the fingers.

If there is no contracture of the long flexors of the fingers, a tendon transplantation is advantageous. In most cases the Bunnell[22] procedure has given the best results. In this operation the flexor digitorum sublimis tendons are removed from their insertions in the middle phalanx, withdrawn from the palm, split, and passed through the lumbrical canals to be attached to the lateral bands of the fingers. The split strands from each tendon should go either to the radial or ulnar side of the fingers so that lateral motion of the fingers is possible. Each finger should have at least one tendon attached to it. The hands and fingers ars splinted for three weeks with the wrist in flexion. During the fourth week light motion is begun, followed by physiotherapy.

Brand[23] modified this operation in restoring function to hands paralyzed by leprosy. Through an incision made on the radial side of the involved fingers (Fig. 162A), the sublimis tendons are divided and then withdrawn through a palmar incision (Fig. 162C). He uses the index finger tendon for the radial side of the index finger. The long finger tendon is split, one half is used for

The ulna is exposed subperiosteally through a three inch vertical incision over the lower third of the subcutaneous border and a graft of the required length is cut with a motor saw This gives a piece of bone that is D-shaped in cross-section and rather more than a centimeter in width The incision is then closed

The graft is passed across the interspace and with the thumb in full abduction and rotation the lines of bone resection are marked on the metacarpals with particular attention to obtaining maximal rotation of the first. Saw cuts are then made so that the edges of each bed are slightly undercut steps about half the diameter of each bone are removed. It is important to ensure that the beds for the graft are in the same plane when the thumb is in full opposition.

The graft is then driven in from one end because of the shape of its cross-section it is held snugly in the slots and rotation is controlled at once. Two drill holes are made through the graft and metacarpal at each end and chromic catgut sutures are inserted to maintain full abduction. The ends of the graft are trimmed to leave no rough surfaces When subluxation of the trapezio-metacarpal joint is present, as may occur in young patients after poliomyelitis, the joint may be excised

Closure is effected by skin sutures only and a plaster-of Paris cast is applied Three weeks later the stitches are removed and a closely fitting plaster is applied for a further period of ten weeks making three months in all

In this series there were only two failures in the entire group It is interesting that five grafts failed to fuse at one end but this did not affect the function very much As a matter of fact a pseudoarthrosis developed in one patient which seemed to help the function of the thumb Brooks believes that if there is any doubt about the benefit derived from such an operation a trial plaster fixation of the thumb in the position of function might be indicated A similar trial using Kirschner wire to impale the metacarpals would be of value Smillie[31] uses a Kirschner wire that transfixes the bone block lengthwise as well as impaling the metacarpals thus fixing this fusion without the use of a plaster-of Paris cast. This is left in place for eight weeks

the long finger and one half for the ring finger The fifth tendon is used only for the fifth finger thus saving the ring finger sublimis for use in restoring opposition to the thumb As each tendon is brought through the lumbrical canal a slit is made in the lumbrical tendon The transferred tendon is passed through this aperture and sutured to the dorsal edge of the extensor expansion just proximal to the interphalangeal joint (Fig 162D)

Riordan[14] reports the use of a tenodesis operation in similar cases based on the Fowler principle (Fig 163) If the metacarpophalangeal joint is stabilized in the position of slight flexion the extensor communis tendon will be able to extend the distal joints He splits the extensor indicis proprius and the extensor digiti quinti proprius into two strands and each slip is then passed through the interosseous space anterior to the transverse metacarpal ligament and inserted into the radial side of the extensor aponeurosis In cases where there is not sufficient strength in the extensor muscles Riordan devised his own method where one half the extensor carpi radialis and extensor carpi ulnaris is split from one third the distance above its insertion and left attached to the metacarpals Each of these strands is split in two and are routed through the interosseous space to the radial side of each finger anterior to the transverse metacarpal ligament. The hand is mobilized in a pressure dressing for three weeks with the wrist in dorsiflexion the metacarpo-

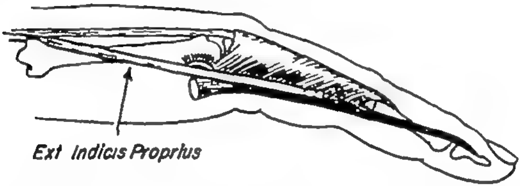

Figure 163 Fowler procedure for paralysis of interosseous and lumbrical muscles. Slip of extensor indicis proprius or extensor digiti quinti proprius is threaded between metacarpals and carried anterior to transverse metacarpal ligament and inserted into lateral bands of extensor apparatus.

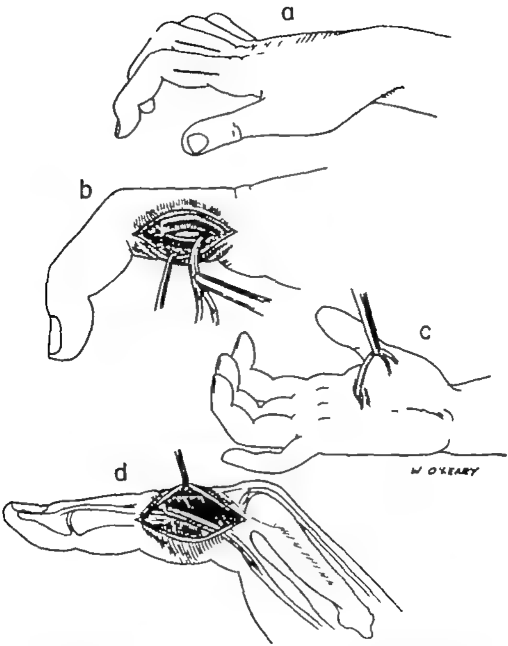

Figure 162. Tendon transfer to restore interosseous and lumbrical muscle function (A) Incision on Radial Aspect of Finger through which (B) The Sublimis Tendon is Incised (C) Palm Incision through which the necessary Sublimis Tendons are withdrawn and re-routed distally through Lumbrical canal (D) Suture of Sublimis slip to Lateral Band.

flexors To restore opposition of the thumb the extensor pollicis brevis tendon is detached proximally transplanted subcutaneously and sutured to the extensor carpi ulnaris which is transplanted around the ulnar side of the forearm

An occasional paralysis secondary to brachial plexus injury or direct destruction of the muscle belly occurs where the wrist flexors are intact but the finger flexors paralyzed To repair this condition the flexor carpi radialis is transferred to the finger flexors. Phalen and Miller[38] believe that extension of the wrist and flexion of the fingers is a more associated movement than flexion of the finger and the wrist hence the transfer of the extensor carpi radialis longus into the flexor profundus tendons is more suitable

The principle of tenodesis may be of value in salvaging hands that have a loss of flexion but good extension Wilson[39] reviewed this problem and found that in certain instances—a tenodesis of the flexor profundus tendons and the flexor pollicis longus to the radius together with a tenodesis of the proximal end of the extensor pollicis brevis into the distal and volar end of the ulna will restore opposition and flexion on extending the wrist

There is a combined deformity of wrist flexion and pronation in various spastic obstetrical palsies In these cases the wrist is held in a flexed position and the hand has a poor grasp Green[40] found transplantation of the tendon of the flexor carpi ulnaris into the extensor carpi radialis longus to be quite effective in correcting the deformity

Tendon Damage

Tendon transfers occasionally are performed in place of grafts When a flexor pollicis longus tendon has been injured along its proximal digital tunnel and repair is unsuccessful the flexor digitorum sublimis of the ring finger is severed near its insertion through a small transverse incision over the proximal phalanx It is then brought out through a wrist incision and threaded along the tunnel of the excised flexor pollicis longus and inserted into the distal phalanx. Fixation is maintained for three weeks with the wrist at 120 degrees flexion and the thumb flexed and adducted

phalangeal joints in flexion and the distal phalanges in extension Following this the cast is removed and active motion begun The operation appears to be most successful when there is marked hyperextension of the metacarpophalangeal joint.

Another function of the interossei other than flexion and extension of the joints of the finger is stabilization of the meta carpal arch [33] When these muscles are paralyzed, there is a tendency for the thenar and hyperthenar eminence to flatten and for the metacarpal arch of the hand to disappear This function is restored by placing a band of fascia between the second and fifth metacarpals thus restoring the arch and anchor ing the bones together This improves the grasp of the hand by a check rein action.

Paralysis of the *first dorsal interosseous* either as a part of a generalized ulnar nerve deformity or due to localized trauma results in a weak or absent pinch To restore this function several tendon transplants have been advocated The most com monly used are a transfer of the extensor indicis proprius into the first dorsal interosseous the use of a short tendon graft placed into the lateral tubercle on the radial side of the proximal phalanx of the index finger or the short extensor of the thumb may be transferred into the tendinous portion of the first dorsal interosseous muscle near its insertion [13,33,36] The hand is placed in a plaster splint with the proximal joint of the index finger held in extension and slight abduction Physiotherapy is begun in three or four weeks Graham and Riordan [37] transfer the flexor digitorum sublimis of the ring finger rerouting it subcutaneously around the radial surface of the wrist and over the anatomical snuff box to the radial side of the proximal phalanx of the index finger where the tendon is inserted either into the bone or the extensor sleeve

Combined High Paralyses of the Median and Ulnar Nerves

These deformities will require a wrist fusion and transfer of extensor tendons to restore flexion Luckey and McPherson [21] found the following combination of transfers satisfactory They transplant the brachioradialis into the flexor pollicis longus and the extensor carpi radialis longus and brevis into the finger

flexors. To restore opposition of the thumb the extensor pollicis brevis tendon is detached proximally transplanted subcutaneously and sutured to the extensor carpi ulnaris which is transplanted around the ulnar side of the forearm

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CHAPTER 20

BONES AND JOINTS

FRACTURES

Following fractures bone reconstruction may be necessary for deformity loss of substance and nonunion Generally deformity may be corrected by osteotomy loss of substance by bone graft, and nonunion by bone grafting or excision of involved bone if it will not impair the function of the hand

Deformity of the fingers usually requires correction when it interferes with grasping or clenching the fist It is corrected by osteotomy re alignment of the bone and either internal or intra medullary fixation Even the distal phalanx may require repair Kelikian[1] reports the case of a violinist who suffered a fracture of the distal phalanx of his middle finger which resulted in healing with radial angulation Consequently the patient could not play his violin and an osteotomy was necessary to restore the bone to its proper position so that he could resume his profession

Metacarpal fractures that have angulated into the palm so that they interfere with the function of the underlying tendons similarly will need re-operation with osteotomy and restoration of proper alignment Malunion of a Colles fracture may be treated in the first two months by manipulation after excision of the head of the ulna A more prolonged deformity will require an osteotomy of the radius in addition to excision of the subluxated head of the ulna

Loss of substance is most often a problem in the metacarpal bones and can be repaired by bone grafting The source of the bone graft may be either the tibia or the iliac crest The graft is fashioned to the proper shape and after excision of the scar tissue is inserted in place For defects in the proximal portion of the metacarpal bone the graft is doweled into the *distal*

fragment and recessed into the carpus at an angle of approximately 30 degrees. Defects of the distal portion of bone should have a graft inserted into the proximal portion and fused with the proximal phalanx at a 30 degree angle. Graham and Riordan[2] use the fifth metatarsal bone to supply adequate articular surface so that mobility of the metacarpophalangeal joint can be salvaged. The bones may be fixed with Kirschner wires. It takes about two months for successful fusion of these grafts. When prolonged immobilization is necessary, it is wiser to immobilize only the involved ray so as to keep mobility of the adjacent joints. Loss of the third or fourth fingers may cause the remaining metacarpal bones to migrate toward each other producing a rotation deformity of the fingers on attempted flexion. It may be necessary to cut the lateral bone transversely at its base and move it internally to the base of the amputated metacarpal.[4,5]

Nonunion of the navicular is the most common nonunion in the hand and its treatment is varied. When both the bone fragments are rarified, it is possible that prolonged immobilization will lead to union. In many cases of delayed healing, bone grafting is necessary and few people can aspire to the results obtained by Murray[6] when he obtained ninety-six unions out of 100 cases. He points out that the bone graft must be large and placed not only through the distal fragment, but well into the proximal fragment. During the operation the articular cartilage of the bone should not be disrupted if one wishes to avoid osteoarthritis. The two fragments should be firmly impacted against each other. After the procedure there is splinting of the wrist so that all the metacarpals and phalanges including those of the thumb are immobilized with the hand in the position of function. This splinting is continued until there is x-ray evidence of union usually seen at a minimum of about ten weeks. Murray used cortical bone which can be chiseled into proper shape for his grafts. When there is evidence of osteoarthritis in the wrist, an arthrodesis of the wrist joint will be necessary.

Bennett's fracture occasionally results in nonunion with weakness of grip, pain on use of the thumb, swelling of the carpometacarpal joint and a dorsal prominence on the proximal end

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form of arthroplasty is indicated provided the skin and soft tissues are in good condition Either the metacarpal head or proximal centimeter of the proximal phalanx is resected and a strip of fascia sutured over the proximal bone so that its gliding surface faces the flexor and extensor tendons around the joint A nylon or acrylic prosthesis to replace the metacarpal head has been successfully used [10, 11]

Metacarpophalangeal thumb joint Habitual subluxation of this joint is a fairly frequent condition It may be repaired by a fascia lata graft reinforcing the anterior surface of the metacarpophalangeal joint of the thumb [12, 13]

Interphalangeal joint Contracture of the proximal and distal interphalangeal joints offers a more difficult problem in reconstruction Generally arthrodesis in a position of function is necessary with the proximal joint held at about fifty degrees flexion and the distal interphalangeal joint at about thirty degrees flexion However recent investigation of capsulectomy and arthroplasty has been undertaken by several surgeons Curtis [14] reports a series of capsulotomies for interphalangeal contracture He removes the lateral collateral ligament and injects hydrocortisone acetate into the affected joint A fine Kirschner wire is introduced to maintain the fingers in flexion and is removed in five to seven days The author finds that if the only limiting factor is the capsule a capsulotomy gives good results On the other hand if it is necessary to free the extensor tendon or perform a tenotomy of the interossei in addition to the capsulotomy the end result is not as satisfactory Carroll and Taber [1] report a series of thirty arthroplasties of the proximal interphalangeal joints They use a midlateral incision elevating the periosteum from the bone severing the capsular attachments and removing the distal third of the proximal phalanx. The wound is closed and the finger placed in the position of function Elastic traction is maintained for six weeks by a Kirschner wire passed through the middle phalanx following which the patient begins use of the finger There were sixteen good and nine fair results in these cases Although it is generally believed that this operation produces an unstable joint it is not the experience of these authors. They did note however that firm direct pres

of the first metacarpal. A repair of this necessitates an open reduction with separation of the malunited fracture site and suturing of the fragments into position using either wire, fascia or nonabsorbable suture This is maintained in a plaster cast with the thumb abducted and some pressure over the base of the first metacarpal as one would do for a fresh Bennett s fracture [7,8]

JOINT RECONSTRUCTION

Joint capsules may become thickened and shortened due to atrophy disuse edema or inflammation Since the collateral ligaments of the finger joints are lax on extension and taut on flexion it is obvious that when these are contracted the joints will be fixed in extension The volar portion of the head of the proximal bone becomes adherent to the anterior capsule thus further blocking flexion of the joint. Occasionally a joint will fix in flexion in which case the anterior capsule is markedly foreshortened

Metacarpophalangeal finger joints If x rays reveal the cartilage to be preserved contracture of these joints may be fairly successfully treated by capsulotomy Through a longitudinal incision on either side of the affected joint the collateral ligaments are approached by retracting the overlying tendon digital vessels and nerves and interosseous tendons The collateral ligament is incised flush at its insertion proximally and distally and completely removed If passive motion reveals insufficient flexion the anterior capsule is explored and if it is adherent to bone it is freed by blunt dissection A transverse incision of the capsule is not done because subluxation may occur and there may be a greater degree of ankylosis than before operation Fowler [9] states that subluxation of the extensor tendons may take place on flexion of the joints which will lead to failure of the operation When this occurs either the lateral expansion of the extensor tendon on the side of subluxation is sectioned or the lateral expansion on the opposite side tightened Following surgery the metacarpophalangeal joints are held in flexion for three weeks either by splinting or traction after which gradual motion is resumed

If the metacarpophalangeal joint surfaces are destroyed some

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sure by the reconstructed digit was impossible Ward[11] reports the installation of an acrylic prosthesis replacing the head of the proximal phalanx with return of complete function of this joint

Carpometacarpal thumb joint Contracture of this joint may be relieved by a capsulotomy However since it is usually associated with an adduction contracture of the thumb additional soft tissue procedures will be necessary

A chronic subluxation of this joint may occur which is repaired by reconstructing the destroyed capsule with a fascia lata graft.[4] An arthrodesis may be necessary in such a case if the navicular bone moves normally However if the navicular bone is ankylosed in the carpus this will give rise to a thumb with marked limitation of motion

Kestler[16] reports on the repair of subluxation of carpometacarpal joints Drill holes are made through the base of the first metacarpal and greater multangular The tendon of the extensor pollicis brevis is divided proximal to the multangular and threaded through the drill holes and sutured to its cut proximal end The thumb is held in abduction for three weeks.

The carpometacarpal joint of the thumb is a common site of osteoarthritis. Clinical features of this disease include pain about the base of the thumb Occasionally crepitation may be felt on moving the joint X ray will show narrowing of the joint space subchondral condensation of bone lateral subluxation osteophyte formation and deformation of the medial and distal angle of the multangular Gervis[17] treated a series of twenty cases by excision of the multangular bone The pain always has been relieved but the functional result often is poor since the thumb is weak Muller[18] advises arthrodesis for this disease The bones are exposed and a narrow slot is cut in the first metacarpal and multangular The capsule synovial membrane and joint surfaces are excised The bones are fitted together accurately and a small tibial or iliac graft is skidded into the slot and tightly impacted

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CHAPTER 21

ISCHEMIC MUSCLE CONTRACTURE

Ischemia of the forearm or hand, even if temporary, may result in destruction of muscle with subsequent fibrosis and contracture. Volkmann was the first to delineate this condition in the forearm and Bunnell the first to clarify it in the hand.

Volkmann's contracture most commonly follows a supracondylar fracture of the humerus or fracture of the bones of the upper forearm, but it may occur after any severe trauma to the elbow region. It has been seen following peripheral embolism. Although this entity first was believed to be caused by venous obstruction in the antecubital fossa, it is now generally conceded that the most important factor is arterial insufficiency.[1-3]

The clinical picture begins with pain in the forearm and hand associated with edema and cyanosis. Hypesthesias and paresthesias may appear in the distribution of the median or ulnar nerves. The radial pulse usually is absent and is commonly mentioned as a characteristic sign. However, Blount,[4] clearly emphasizes that the importance of the radial pulse has been unduly stressed. The pain, cyanosis and swelling are indications for release of the degree of flexion of the elbow even if the radial pulse is present. If the condition is not remedied during the first few days, the pain, cyanosis and swelling persists and blebs appear in the skin with or without associated skin sloughing. In time the "claw" hand deformity becomes evident with atrophy of the forearm and numbness of the hand. The contracted muscles may produce a severe flexion deformity of the fingers (Fig. 164) so that little extension is possible. In other cases various degrees of shortening occur. For instance, extension of the fingers may be possible if the wrist is flexed (Fig. 165). A marked pronation contracture may occur.

Nerve lesions are due to ischemia.[3] The nerve is shrivelled and hard and all the structures are replaced by a dense mass of collagen

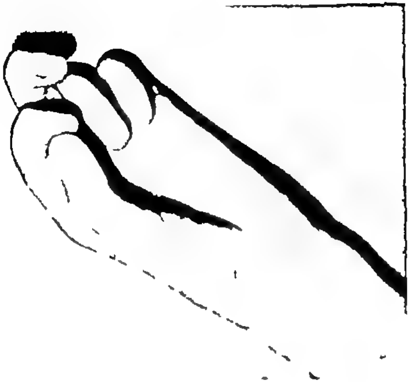

Figure 164 Volkmann's Contracture. Atrophy of soft tissue of hand plus severe contracture of flexor tendons.

Figure 165 Volkmann's Contracture Less marked shortening of flexor tendons Fingers can be extended if wrist is flexed.

Treatment should be started as soon as pain cyanosis and edema are evident. If the elbow fracture was treated by acute flexion the elbow is extended to see if the radial pulse will return and the pain edema and cyanosis subside A supracondylar fracture may be immobilized by a Kirschner wire placed through the olecranon or by open reduction If the change in position does not restore the circulation the antecubital space is explored to examine the brachial radial and ulnar arteries The arteries may be constricted torn thrombosed or caught between bone fragments and if they are placed in their normal bed and are still constricted this area of artery is resected Crystal reports a case in which a thrombectomy was performed twenty hours following injury[6] Circulation was restored with an almost complete cure Dorsal sympathectomy may be of benefit also

Another method of treatment of the acute condition is by immediate operation on the forearm and excision of necrotic muscle It is believed that this may prevent the contracture thus decreasing the disability However the difficulty here is that one cannot be sure that such muscle will not regenerate For example Horn and Sevitt,[7] followed the regeneration of a tibialis anterior muscle by muscle biopsy for weeks following a rupture of the popliteal artery At the beginning the muscle was brown dry friable and quite avascular Histologic section of this muscle nineteen weeks after injury showed necrotic muscle with absence of nuclei and discoidal fragmentation A second biopsy fifty seven weeks after injury showed no necrotic muscle in the section A regeneration of muscle took place pointing out the regenerative power of human muscle and presenting the problem of deciding which muscle to excise at the time of initial surgery Griffiths,[8] suggests that perhaps the response to intravenous curare or the persistence in the muscle of injected radioactive substances might be a useful guide.

Fontaine *et al*[9] found that in experimental Volkmann s contracture sectioning of the peripheral nerves greatly reduces the strength of the contracture They believe that injecting novocain into the region of the muscle contracture may help by permitting extension of the contracted muscle mass

For the late condition a long period of physiotherapy with dynamic splinting to overcome the contracture should be followed. Efforts should be made to restore motion in all the joints of the fingers, hand and wrist. If this is not sufficient to overcome the deformity, some operative procedure may be necessary.

Tendon lengthening is one of the standard procedures at this stage. Through an antero-lateral incision in the forearm the skin and fascia are divided to expose the superficial and deep flexor muscles and tendons. An effort is made to remove as much scar tissue as possible after freeing the nerves and tendons from adhesions. Stripping of the flexor digitorum profundus, flexor pollicis longus and flexor digitorum sublimis from their origin with advancement along the forearm may be done.[10] If this does not permit adequate extension of the fingers, two oblique incisions are made two centimeters apart three-quarters of the distance across the tendons and the tendons stretched. If there is a flexion deformity of the elbow, a capsulotomy of the elbow joint may be beneficial. Section of the pronator teres and quadratus may be necessary to permit supination.

Mallet-Guy[11] describes a tendon transfer which he finds useful. An incision is made in the forearm and the deep flexors of the fingers are cut. Another incision is made in the palm and with the fingers flexed as much as possible the superficial tendons are cut. When the fingers are extended to their fullest, the profundus tendon is cut again and the distal profundus tendon sutured to the proximal superficial tendons.

Parkes[12] describes another tendon transfer in which the flexor carpi radialis, palmaris longus and flexor carpi ulnaris are completely divided at the wrist to permit dorsiflexion. The tendons of the flexor digitorum sublimis are resected and the tendons of the flexor digitorum profundus divided high enough above the wrist to avoid retraction of the distal stump into the carpal tunnel when the fingers are fully extended. The flexor pollicis longus is similarly divided to permit extension of the thumb. The tendon of the extensor carpi radialis longus is divided at its insertion and freed for a considerable distance from the extensor carpi radialis brevis. This muscle with its tendon is rerouted in as straight a line as possible from its origin to the

front of the wrist where it is buttonholed through the four tendons of the flexor digitorum profundus and fixed in the usual way Correct tension is made at the suture line to be sure that full advantage is taken of wrist movement This operation is actually a tenodesis which restores flexion of the fingers by means of the trick movement of dorsiflexion It is interesting that the lack of voluntary power of the thumb produced by the operation causes no material disability provided there is active opposition of the thumb

In long standing deformities the wrist may be flexed to such a degree that a dislocation is produced In these cases it is necessary to remove sufficient bone to obtain an extended wrist and hand This is done by resection of one or two rows of carpal bones and removal of part of the radius and ulna [13] The wrist is fused at about 20 degrees extension Following this one of the muscle transplants may be possible

A similar condition may occur in the intrinsic muscles of the hand following encasement of hands in plaster-of Paris or tight elastic bandages This also may follow damage to the great vessels it may accompany Volkmann s ischemic contracture it has been seen following severe thermal and soft tissue crushing injury and it is known as *ischemic contracture local in the hand* [14] There is a characteristic position of the hand with the metacarpophalangeal joints held in flexion the interphalangeal joints in extension and a straight thumb pressed against the palm. This deformity is due to contracture of the interosseous and lumbrical muscles and is referred to as an *intrinsic plus* position If the metacarpophalangeal joints are passively forced into extension the distal interphalangeal joints cannot be flexed (Fig 166) However if the metacarpophalangeal joints are held in flexion the distal joints can be flexed

In mild cases splinting of the hand may overcome the deformity however in most cases operation will be necessary If interosseous function is still present the interosseous muscles may be separated from the metacarpals by subperiosteal dissection and advanced distally Through suitable dorsal incisions a small curved periosteal elevator is inserted around the metacarpals releasing the insertion of the interossei from the bones The

muscles are allowed to advance distally until the proximal finger joints extend and the distal finger joints flex.

If the intrinsic muscles are too fibrotic to function or if a previous stripping has been unsuccessful, a tenotomy of the lateral bands of the fingers will be necessary. A single midline incision on the dorsum of the proximal phalanx extending from the level of the metacarpophalangeal joint to the proximal interphalangeal joint will expose the involved lateral bands. The extensor hood at the level of the metacarpophalangeal joint is made up of three components: the long extensor, the transverse fibers of the intrinsic muscles which exert action on the metacarpophalangeal

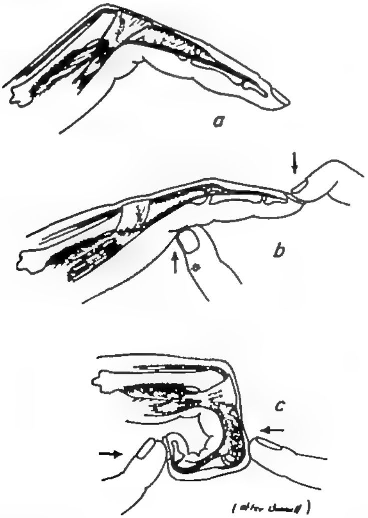

Figure 166 "Intrinsic plus" deformity of finger. (a) characteristic position. (b) forced extension of metacarpophalangeal joint prohibits flexion of finger. (c) flexion of metacarpophalangeal joint permits flexion of finger.

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joint and the oblique fibers of the intrinsic muscles which extend the interphalangeal joints It is essential that the oblique fibers only be excised thereby releasing the extensor contracture on the interphalangeal joints but preserving the transverse fibers which exert a flexor action on the metacarpophalangeal joint A splint is applied to this joint which is held at 180 degrees extension and active motion of the fingers is begun early

When this condition involves the web space of the thumb various procedures will be necessary The contracted skin is excised and the intrinsic muscles stripped from the thumb After the defect is skin grafted from hinge-to-hinge the full thumb spread may be maintained by transfixing the metacarpals of the thumb and index finger with two Kirschner wires At a later date tendon transfer to restore opposition to the thumb may be indicated.

Thompson and Mahoney[13] describe a contracture similar to Volkmann's contracture in the lower extremity following fracture of the femur

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